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ABSTRACT

This publication relates the experiences of seven K-8 teachers who participated in a science education doctoral cohort group during which each of the teachers engaged in a different real-world scientific research project. The idea was to immerse teachers in scientific research so that they could experience inquiry in science first-hand and become part of the culture and discourse of science through a contextual learning experience. The chapters in this book highlight how these experiences were empowering, gave the teachers confidence in themselves, and renewed the teachers' energy to teach science. The ways and methods through which teachers can immerse themselves in scientific research and the impact scientific research can have on students are also discussed. Chapters include: (1) "Teachers Learning Inquiry through Scientific Research" (Penny J. Gilmer); (2) "Teachers Can Be Scientists, Too!" (Jacqua L. Ballas and Terrie L. Kielborn); (3) "How a Crab's Sense of Smell Changes the Life of a Teacher" (Kathleen R. Foley); (4) "Investigating Fish Mortality: A Science Teacher's Learning Experience" (Lori Livingston Hahn); (5) "Ghost Shrimp and Fish Bring Real-World Experience to a Science Classroom" (Joseph Brock); (6) "Blossoming of Science Involvement through Algae Research" (Terrie L. Kielborn); (7) "Scientific Inquiry: A Journey for a Teacher and Students" (Yvette F. Greenspan); (8) "Learning and Growing as a Scientist and Science Educator" (Marcie L. Bosseler); and (9) "Forming Partnerships: How a Teacher Can Become Involved in Scientific Research" (Terrie L. Kielborn). (WRM)

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# MEANINGFUL SCIENCE:

## Teachers Doing Inquiry + Teaching Science

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*Improving Learning through Research & Development*

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# MEANINGFUL SCIENCE

## Teachers Doing Inquiry + Teaching Science

Edited by
*Terrie L. Kielborn &*
*Dr. Penny J. Gilmer*

with a Foreword by
*Dr. Francena Cummings*

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SERVE
*Improving Learning through Research & Development*

Associated with the School of Education
University of North Carolina at Greensboro.

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- Disseminating exemplary mathematics and science educational instructional materials
- Providing technical assistance for the implementation of teaching methods and assessment tools for use by elementary and secondary schools students, staff, and administrators

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# About SERVE

SERVE is an education organization with the mission to promote and support the continuous improvement of educational opportunities for all learners in the Southeast. To further this mission, SERVE engages in research and development that addresses education issues of critical importance to educators in the region and provides technical assistance to SEAs and LEAs that are striving for comprehensive school improvement. This critical research-to-practice linkage is supported by an experienced staff strategically located throughout the region. This staff is highly skilled in providing needs assessment services, conducting applied research in schools, and developing processes, products, and programs that inform educators and increase student achievement.

As the new millenium approaches, SERVE is preparing to address emerging 21st-century issues, such as persistent achievement gaps between minority and non-minority students, massive teacher training needs, and rising numbers of limited English proficient students. Committed to a shared vision of the future of education in the region, the SERVE organization is governed by a board of directors that includes the governors, chief state school officers, and key legislators from Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina, and representative teachers and private sector leaders. SERVE's core component is the Regional Educational Laboratory program. SERVE is one of 10 organizations, funded by the Office of Educational Research and Improvement, U.S. Department of Education, that provide the services of the Regional Educational Laboratory program to all 50 states and territories. These Laboratories form a knowledge network, building a bank of information and resources shared nationally and disseminated regionally to improve student achievement locally. SERVE has additional funding from the Department in the areas of Migrant Education and School Leadership and is the lead agency in the Eisenhower Mathematics and Science Consortium for the Southeast and the Southeast and Islands Regional Technology in Education Consortium.

Based on these funded efforts, SERVE has developed a portfolio of programs and initiatives that provides a spectrum of resources, services, and products for responding to local, regional, and national needs. Program areas include

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- School Development and Reform
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In addition to the program areas, the SERVE Evaluation Department supports the evaluation activities of the major grants and contracts and provides evaluation services to SEAs and LEAs in the region. Through its Publishing and Quality Assurance Department, SERVE publishes a variety of studies, training materials, policy briefs, and program products. These informative and low-cost publications include guides to available resources, summaries of current issues in education policy, and examples of exemplary educational programs. Through its programmatic, evaluation, and publishing activities, SERVE also provides contracted staff development and technical assistance in many areas of expertise to assist education agencies in achieving their school improvement goals.

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National Science Foundation grant (#ESI 9253170) supported four of these teachers during Science FEAT in their scientific research, which set the stage for research described here. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the National Science Foundation.

The Chemistry Department at Florida State University provided travel funds for me to visit two of the teachers during their scientific field experiences.

The Eisenhower Consortium for Mathematics and Science Education at SERVE funded us to write and edit this monograph.

*–Penny J. Gilmer*

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*It's difficult to teach using inquiry methods if you haven't learned that way yourself.* [1, p. 21]

*Even when teachers have had the college course work we would like them to have, they're often unattuned to how they ought to be teaching because they haven't personally experienced it.* [1, p. 21]

*For example, one of the best ways for high school teachers to deepen their science knowledge is to spend time in places where frontier science is being done.* [1, p. 21]

*People need to think about opportunities other than workshops and institutes and to craft partnerships with science-rich organizations so more opportunities are available for teachers to learn at sites where science and mathematics are being used.* [1, p. 21]

[1] Sparks, D. (1997). Reforming teaching and reforming staff development: An interview with Susan Loucks-Horsley. *Journal of Staff Development* 18(4):20-21



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# Foreword

*by Francena D. Cummings, Ph.D.*
*Director, Eisenhower Consortium @ SERVE*

The release of the National Science Education Standards in 1996 increased the dialogue in the science community about meaningful science for all students. This dialogue focused on what students should know and be able to do in science. Inquiry is at the heart of the standards-based classroom. In the Standards, inquiry is cast as an instructional method and as content (inquiry skills). When this process is evident in the classroom, we see students, under the directions of the teacher, actively engaged in activities that help them develop knowledge and understanding of scientific phenomena.

If science teachers are expected to teach in this manner, they must experience science in the same way. We know, however, that teachers are often not taught in this manner. Consider the following:

> *Typically, college courses don't teach teachers in ways they're now being asked to teach. It's difficult to teach using inquiry methods if you haven't learned that way yourself. Because science teachers have learned science by mastering a body of facts and principles, they tend to see science in the same way.*[2] (Loucks-Horsley, 1997, p. 21)

What kind of learning opportunities can help teachers learn science through inquiry? The Teachers Learning Inquiry through Scientific Research Project at Florida State University provided a unique opportunity for teachers to engage in scientific research with scientists who served as mentors. In these working relationships, teachers were able to deepen their scientific content knowledge as well as their skills and understanding of "science as inquiry." Moreover, this small cohort of teachers had an opportunity to form a learning community in which they could share their experiences and make plans for changes in their classrooms. With the partnerships of the research scientists and the university professor, these teachers had time to do science, reflect on the scientific experience alone and with colleagues. Most important, they had opportunities to transfer some of their new knowledge and skills to their classrooms.

In this monograph, teachers tell their stories of working with scientists, working with each other, and how their experiences changed their classroom practice. They share their stories in compelling ways, hoping that they can inspire others to join in this kind of professional learning. They share both the cognitive and affective aspects of their experiences and further validate our need to look for balance in the classroom. Curiosity, open-mindedness, persistence, expectations, and risk-taking matter, and these teachers remind us of how these factors emerge in quality learning environments. We must continue to encourage partnerships between scientific agencies and educational institutions.

Mary Budd Rowe purported that:

> *Scientific knowledge is not something gained by introspection alone. In contrast to the humanities, where the main test of an idea is whether it makes you "feel right" and is accepted by others, in science ideas must be subjected to objective verification. In science one comes to realize that an idea is not necessarily valid just because it seems right or reasonable. The idea must be tested against the performance of nature and against the network of other ideas into which it is connected or which it refutes.*[1] (1978, p. 472)

It is my belief that the Teachers Learning Inquiry through Scientific Research Project is a professional development model that allows teachers to engage in testing against the performance of nature. It also provides a rigorous agenda for objective verification. The Eisenhower Consortium @ SERVE is proud to continue its partnership with Florida State University in the development, publication, and dissemination of this monograph, *Meaningful Science: Teachers Doing Inquiry + Teaching Science*. We offer this product as yet another tool that may help make a difference in teaching meaningful science for all children.

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References

[1] Rowe, Mary Budd. (1978). *Teaching Science As Continuous Inquiry: A Basic*. New York: McGraw Hill.

[2] Sparks, Dennis. (1997). Reforming teaching and reforming staff development: an interview with Susan Loucks-Horsley. *Journal of Staff Development*, 18(4): 20-23.

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## Prologue

*In "Teachers Learning Inquiry through Scientific Research," Penny J. Gilmer describes the rationale and goals for a project in which seven K-8 school teachers in a doctoral cohort group in science education participated in different real-world scientific research projects. The idea was to immerse teachers in scientific research so that teachers could experience inquiry in science first-hand and become part of the culture and discourse of science in a "contextual learning" experience. Research projects started in summer or fall and generally extended further into the teacher's school year. The teachers chose environmental research projects that were relevant to their lives and to those of their K-8 students.*

*The experiences were empowering and gave the teachers confidence in themselves and renewed energy to teach science. Interactions between teachers and mentoring scientists were powerful forces in this change. Teachers all chose to work with scientists who worked near their school site so that collaboration and partnership of teachers with scientists and research laboratories might continue and include the teacher's K-8 students. Early results suggest that their K-8 students became more involved in learning, doing, and thinking about science.*

# Teachers Learning Inquiry through Scientific Research

*Penny J. Gilmer*

## Idea for the project

Five middle school science teachers and two elementary school teachers from a doctoral cohort group in science education participated in scientific research for a semester or more. The idea was to encourage practicing K-8 teachers to experience real-world scientific research, to participate in planning and execution of experiments, engage in inquiry, ask questions, analyze data, plan and execute follow-up experiments, and communicate results, rather than just reading or hearing lectures on "facts" of science. National Research Council's *National Science Education Standards* (NSES)[11] encouraged these kinds of activities for our K-12 students. However, for teachers to be able to do this, they must experience it themselves. The NSES defines *scientific inquiry* as follows:[11]

> *Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (p. 23).*

Scientific Work Experiences for Teachers (SWEPT) sponsored by the National Science Foundation and the Triangle Coalition for Science and Technology Education,[16] has similar goals for practicing teachers.[1] In their summer program, teachers are paid to work with scientists or engineers who supervise their work.

Through experiencing inquiry and the process of science directly, teachers may be better able to integrate science content and build understanding. We wanted to see if teachers can learn science in the context of "researching" subject matter, i.e., searching subject matter again. All research projects focused on environmental research. We have referred to this type of research as *contextual learning in science.*[5]

Previously, four of the teachers in this study had engaged in scientific research as part of a cohort master's degree program in science education called Science FEAT (Science For Early Adolescence Teachers).[12] In the second summer of a three-year program, teachers had a choice of projects and of scientists with whom to work. All research sites in the master's degree program were near the university—Florida State University—not near their middle schools. Because of large distances between the teachers' schools and the university, it was not possible to continue those projects once teachers returned to their schools.

For the project described here, teachers chose to work with scientists who worked near their school, with hope that research might continue during the school year with the teacher and her/his students. Of four Science FEAT teachers, Lori Livingston Hahn worked with federal Environmental Protection Agency, Jacqua Ballas with state Department of Environmental Protection, Kathy Foley at the Whitney Laboratory (a marine laboratory associated with University of Florida), and Joe Brock with National Marine Fisheries Service. Jacqua collaborated with another teacher, Terrie Kielborn, from her middle school. Terrie was also taking graduate-level classes but had not been in Science FEAT. In addition, there were two elementary school teachers, Yvette Greenspan and Marcie Bosseler, who entered the doctoral cohort program later.

As a Ph.D. biochemist and chemistry professor at the university, I provided overall guidance and supervision for these seven practicing teachers. In all but one case, research extended to more than one semester. I have maintained e-mail contact with all teachers and mentors at research sites. In addition, I visited four of the seven teachers at research sites during their research to gain a greater understanding of the teacher in her/his research setting, of the directing scientist, and of the scientific research project. Four of the five teachers who did research during the first summer assembled to share their research experiences and to discuss whether (and how) their experiences influenced their beliefs and actions about science.

*"This was powerful for influencing the community of teacher educators."*
*–Kathy*

The science education research reported in this paper focused on the following questions:

- As teachers construct new understandings of the nature of scientific inquiry and processes of science through authentic research, do they begin to think differently about scientific inquiry and how they might teach science?
- Are teachers starting to teach science differently after they have actively participated in scientific research?
- Are K-8 students starting to engage more in inquiry-based science when it is taught by teachers who have experienced authentic scientific research?

## Theoretical underpinnings

Primary theoretical underpinnings for this project include radical[6] and social constructivism.[15] People make sense of their understandings of the world based on their prior experiences. Therefore, we expect that teachers may build new constructions of science based on experiences in a science research context while immersed in the culture of science. Instead of teaching abstracted science, teachers with research experiences may offer opportunities for their students to engage in scientific activities such as those in which they participated. Then the teachers' K-8 students may construct science as it is actually done. Students may learn that science is a process of understanding and that with time their understandings change in the light of new data. The students may have opportunities to learn that science is dynamic and interesting,[11] not just a series of "facts" to be memorized. They may see that science is a way of making sense of the world, especially because research is focused on local environmental issues.

**Contextual learning** *in science is learning in the context of doing, thinking, speaking, and experiencing science.*

"Contextual learning" in science is learning in the context of doing, thinking, speaking, and experiencing science. Social constructivism is based on individuals learning within a social situation, with a community of learners. In contextual learning, one learns within the culture of science with other practitioners, using equipment, logic, creativity, analytical reasoning, inquiry, and communication needed to conduct scientific research. Contextual learning is a step beyond "hands-on" and "minds-on" science. It is actually doing, thinking, speaking, and experiencing science.

Teachers who experience scientific research have opportunities to engage actively in the discourse or language of science.[9] At first, for teachers in this study, the language of science may have seemed like a foreign language, with some words that teachers know already being used in other contexts. In addition to words with new meanings and totally new words, such as the Latin names of the species, there were many acronyms to learn and understand.

Teachers had access both to their research mentor on the research site and to me as the supervising professor at the university, with whom to speak and utilize the language of science. By using the language of science and negotiating meanings of words, teachers may learn science in a way that enables understanding at a deeper level. Tobin has addressed co-participation as "the presence of a shared language that can be accessed by all participants to communicate with one another such that meaningful learning occurs."[14, p. 371] All teachers but two had significant interactions with other scientists with whom they could learn the experimental system, ask questions, argue about findings, and communicate results and implications of research.

## Methods

I employed qualitative research methods in this study,[2,3] utilizing fourth-generation evaluation,[7] employing member checks and peer debriefing to increase reliability and trustworthiness of data. Data included field notes, e-mail, and other correspondence with teachers and their research mentors, professional papers written by the teachers, science research reports, teachers' portfolios of their learning, and visits to some research sites and teachers' K-8 classrooms.


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*Three questions for the study:*

*As teachers construct new understandings of the nature of scientific inquiry and processes of science through authentic research, do they begin to think differently about scientific inquiry and how they might teach science?*

*Are teachers starting to teach science differently after they have actively participated in scientific research?*

*Are K-8 students starting to engage more in inquiry-based science when it is taught by teachers who have experienced authentic scientific research?*

In my role as a university biochemist in a chemistry department, I suggested to seven teachers that each of them should try to find a scientist, who could supervise their research at a laboratory located near their respective middle schools. I offered them graduate credit in science. Teachers selected a topic that would be meaningful both to them and their students. All teachers chose environmental research projects that were biochemically or biologically oriented.

I maintained weekly contact with teachers during the study through e-mail, with four on-site visits to research laboratories, two visits to the teachers' elementary school classrooms, and a group meeting of four teachers (with other prospective and practicing teachers and faculty) near the end of the first summer at the university. Each teacher maintained a log book, which contained data and reflections on the impact that this experience was having on their understanding of science. Each teacher submitted a written final report on their learning of science; some of these were in a portfolio format.

Teachers' written reports included projections of how they thought they might teach differently. One teacher, Kathy, was teaching marine science to middle school children at the same time she was conducting her scientific research, so in her summer report she included a perspective on how she was teaching differently. Both Yvette and Marcie taught elementary school while they were conducting their scientific research. Each supervising scientist submitted an evaluation letter on the teacher's work in the research laboratory. Ongoing communication with teachers has continued since the first summer, by both e-mail and visits in person. Four of the teachers (Kathy, Lori, Jacqua, and Terrie) presented our preliminary findings with me in a paper set at the 1997 annual meeting of National Association for Research in Science Teaching. Terrie co-presented the project with me at the Association for the Education of Teachers in Science annual meeting in 1999.

Of the four Science FEAT graduates in this study—Kathy, Lori, Joe, and Jacqua—each one found a scientist who was willing to work in a research laboratory near their school. Kathy remembered having worked previously with an environmentalist who was interested in educational issues. He agreed to supervise her research at a marine science laboratory while she was enrolled at Florida State University. Lori chose an environmental project with a researcher eager to work with her at the U.S. Environmental Protection Agency. In Lori's case, her research mentor had always been interested in educational issues, and was glad for opportunities to collaborate. Jacqua worked with a middle school teacher, Terrie, and a researcher in environmental research at the Division of Parks and Recreation and at a state park near their middle school. Jacqua had learned about this park as part of an environmental program offered there, so she and her students were familiar with it. Joe had always loved fishing, and he knew of a research site near his home and school where he could conduct research on transport of snapper and other fish larvae.

The other three teachers were Terrie (who originally became involved in the project because she worked with Jacqua), Yvette, and Marcie. Terrie found a research scientist within the University of Florida TRUE program during the second summer. Yvette chose to work with a scientist at the Parrot Jungle and Marcie with one at the Garden, an affiliate of the Center for Plant Conservation.

## Impact of contextual learning on teaching and learning

This monograph describes the research experiences of seven teachers. However, this chapter will give my perspective as the supervising research scientist on what the teachers learned and how this impacted their understanding of science and their teaching in K-8 classrooms. The results on the effects of the participants' teaching are still preliminary.

## Jacqua and Terrie with cogongrass in sandhill community

*Jacqua(left) and Terrie*

Jacqua and Terrie's project involved a mapping study of populations of cogongrass prior to an intensive herbicide treatment for removal of this exotic plant species (originating in southeast Asia) at a local state park. Their project was to locate and classify densities of cogongrass in marked park quadrants. Jacqua and Terrie each kept a research journal, which they shared with me, of their activities, observations, questions, and classroom applications that occurred to them during the project. Terrie received credit for her research through another university. Their journals included observations of wildlife and sightings of other exotic species. Jacqua and Terrie also read many research articles on cogongrass at a local university library. Using an existing quadrant map, aerial photographs, and field searches, Jacqua and Terrie mapped densities of cogongrass in each quadrant of the state park. They learned the importance of teamwork as they drove an all-terrain vehicle (loaned by the park) over hundreds of acres, reading the map and estimating cogongrass density.

You can sense the excitement, satisfaction, and challenges of their research experience, as shown in an e-mail update Jacqua sent me:

> *The project is moving along, and we are enjoying our time to research. We go out early in the morning and spot a great amount of wildlife as we map. So far we have seen groups of wild turkey, white-tail deer, armadillo, and a swallowtail kite (we think, not sure). We come in before the heat of day overtakes us. The only problem so far is an aggravating case of chiggers.*

A grant to remove the cogongrass from the park property, of which Jacqua and Terrie were a part, funded treatment of 50 acres of cogongrass, which was dispersed throughout several hundred acres of natural sandhill areas. Therefore, it was important that researchers knew which areas had the highest density of cogongrass for herbicide application and also for evaluating effectiveness of treatment. Because of the high cost of the herbicide, it was important to know the amount of cogongrass.

*About Jacqua and Terrie: I think that it was good for the teachers to work as a team, to have each other to answer questions, and to help with the physical work.*

Jacqua reflected more on how research would impact their teaching and how important it was to Jacqua and Terrie to work as a team of scientists:

> *Today we discussed how important map reading skills are to biologists, weather, and space scientists. This is an insight we have gained from*


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*doing this project that we will share with our students. We also talked about how much harder it would have been to work alone. It is so much easier to have a driver and a navigator. Also, when we run into grasses that puzzle us, it helps to have another person there to discuss it with.*

I think that it was good for the teachers to work as a team, to have each other to answer questions, and to help with the physical work. They worked in a state park that was close to their schools, and their middle school students cared what happened to the ecology of their area.

After working together all summer, Terrie and Jacqua, who work at the same school, developed a *Teacher's Guide to Environmental Monitoring*, which they used not only in their school but statewide. They designed the manual to help teachers who were interested in doing environmental monitoring at their schools—for example, water quality studies. Jacqua was hired for one year on special assignment to develop curricula in environmental studies.

This first research experience was a stepping stone for Terrie's decision to switch to Florida State University for her graduate program. It led to her wanting to conduct more scientific research in the following summer. Other research studies have engaged students in monitoring pine beetle damage to pine trees. Therefore, I think the experience of Jacqua and Terrie during the first summer had a profound effect, especially on Terrie.

Three high school students have done research on cogongrass for Regional Science Fair. One of these students was mentored by Jacqua and Terrie, after they completed their summer study.

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## Kathy and crustaceans

*Kathy showing a crab.*

Kathy's research involved cataloging morphological characteristics of the aesthetasc (i.e, olfactory structure involved in the sense of smell) in a variety of crustaceans, including blue crab, sand fiddler crab, mud fiddler crab, and a deep water crab. Her research goal was to understand how organisms adapt to stress, including the stress of changing salt concentrations, mimicking how salt water flows into marshes.

As the project started, Kathy read a series of research articles of previous work on blue crabs that had been conducted in this laboratory. Aesthetasc sensilla of the blue crab are highly specialized, enabling blue crabs to go from areas of high salinity to very low salinity. This is very important to blue crabs because they mate only once in their three-year lifetime.

Kathy utilized a macro lens on a dissecting microscope, observing and drawing antennules. She said, "I found this simply beautiful, the nose and the simple beauty of observing nature left me feeling in awe." Using differential interference contrast microscopy, she videotaped movements of four species of crustaceans and documented their sensory structures. Kathy had

*About Kathy: Kathy's life was immersed in marine science, teaching and researching by day and reading journal articles late into the night, much like that of a scientist.*

to shorten hours of recorded videotape down to about 12 minutes, and in the process she made a mistake on identification of certain species. Her mentoring scientist worked with Kathy to fix this. Kathy's remake of the videotape was an important stepping stone for her in understanding what it is to do science. She grew in confidence with this experience.

Kathy showed part of this videotape at the NARST '97 meeting during our paper set on teachers conducting scientific research. Since then I have studied her videotape and found that she learned the science content deeply and shared her scientific discourse well on the videotape. Two years later, she can still speak clearly on the topic of her research.

While Kathy was conducting her research, she was simultaneously teaching marine science half-time to adolescents. She had opportunities to have her students participate in collecting marine samples. Kathy's life was immersed in marine science, teaching and researching by day and reading journal articles late into the night, much like that of a scientist. In an e-mail to me, Kathy commented on her experiences:

> *The experiences I have gained this summer doing research are being applied to my summer middle school students, as I experience them. A truly evolutionary process, I am totally delighted with how the summer research experience is turning out. I know more about crustaceans than I [could] have imagined.*

Her research advisor provided a powerful example by telling Kathy that he did not always have answers to her many questions and that scientists had many more questions than answers. This empowered Kathy in her own classroom because when her students asked her questions that she did not know, she responded similarly and worked with her students to find answers and encouraged them to ask more questions.

Kathy also developed many technical skills. Many scientists have been quite ingenious, building specific equipment to meet the needs of the project. Kathy enjoyed this type of problem-solving. The research experience was particularly helpful and challenging for her classroom, and she learned much information regarding community resources. Her field experiences during that summer were quite different from her chemistry laboratory research project during the Science FEAT program. Her two research experiences—one with the crabs and the other in chemistry during Science FEAT—complemented each other, with one in the field and one inside a laboratory.

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## Lori in an environmental laboratory

During the master's cohort Science FEAT program, Lori had selected a research project in archeology, examining field samples in an effort to develop archeology lesson plans for students. She had chosen that research experience because she was pregnant at the time and, therefore, did not want to work in the field or in a laboratory. However, she still yearned for a laboratory experience in which she could immerse herself in the culture and practice of science.

In the study described in this monograph, Lori chose a biochemistry project for her contextual learning, at an Environmental Protection Agency

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*Lori is analyzing fish liver samples.*

(EPA) laboratory near her middle school. The purpose of her scientific research was to establish a method and determine the cause of fish mortality when a marine algal toxin was suspected as a cause. She utilized high-performance liquid chromatography (HPLC) on extracted liver preparations from fish that had died in massive fish kills. Microcystin, a cyclic peptide, was the suspected agent responsible for a fast death factor produced by a type of cyanobacteria, a blue-green algae. She extracted livers of dead fish with organic solvents and processed samples for analysis by HPLC. Microcystin was not found to be present in these particular liver tissue samples. During my visit to her research site, Lori showed me her HPLC equipment, how she programmed the computer, and what her experimental data looked like. We met with her research advisor and shared common interests in science and education. Lori worked many hours by herself with the sophisticated HPLC equipment, while she prepared and analyzed her samples. Her research mentor would stop to see her once a day, to answer questions, and guide her.

*About Lori: She still yearned for a laboratory experience in which she could immerse herself in the culture and practice of science.*

In an e-mail to me during the summer, Lori reflected on her experience:

> *So far we have not found any microcystins in samples. Cause of fish mortality is "unknown" at this point. However, my learning has certainly progressed. While we have not been able to answer one of our questions, my understanding of using HPLC technique to detect presence of toxins in tissues is clear. Benefits of such a technique are endless. I find it fascinating that by using standards of these toxins, as well as other substances, the UV [ultraviolet] spectrum which remained always constant can reveal their presence.*

I think that Lori learned more chemistry in this summer experience than she had in several chemistry courses as an undergraduate. Since that time, Lori has job-shared a teaching position while her son is still young. While job-sharing, she has not been a science teacher, but she has brought science into her classroom when teaching reading, by developing units on science, technology, and society. She found that her students were interested in real-world examples of science.

For her dissertation project, Lori has chosen to study how practicing middle school teachers and prospective middle school teachers respond to working together with a scientist in a research project, as part of a new NSF collaborative grant in teacher preparation. She will conduct a qualitative study in the hermeneutic tradition of addressing the claims, concerns, and issues of the various stakeholders. I believe that she chose this study because of the profound effect the research experience has had on her understanding of the content and processes in science. She wants others to experience this, too, and wants to learn from studying others.

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## Joe catching snapper fish larvae

Joe was one of two teachers I visited on the research site during the first summer. He was involved in a project that examined recruitment of gray snapper and other fishes into St. Andrews Bay, near Panama City, Florida. Joe had worked on a project with the Florida Department of Fisheries during Science FEAT project, so he was delighted when he found he could continue research with National Marine Fisheries Service.

*Joe harvesting snapper larvae.*

My 14-year-old daughter and I went with Joe to collect samples in sea grass beds of St. Andrews Bay. Several other researchers joined us on the boat on a beautiful summer day. We were trying to time it just right to get to the site where nets had been set up and anchored before the tide changed. Despite our efforts, the tide had already started to come back in, so the water was not clear there, but we were able to retrieve larval fish from Joe's collection system. Once we had our samples, we moved out a little further into the bay toward the Gulf, maybe another 100 meters. There, you could see that the tide had not shifted yet, and the bottom of the bay was absolutely clear, just as Joe predicted. Dolphins came up to our boat and seemed to laugh with us. Back in the laboratory, I watched Joe carefully remove sea grass from tiny larval samples, which he saved in a small glass bottle. He was so excited to see the number and types of fish that he had harvested. Joe shared his perspective:

*About Joe: Dolphins came up to our boat and seemed to laugh with us.*

> *The research this past summer has impacted how I view science dramatically. I think all science teachers should have the opportunity to become immersed into the culture of science and [see] how scientists operate through the course of research. Perhaps one of the most important lessons I learned is that scientists spend just as many hours writing proposals as they spend in actual research. They are just as subject to mountains of paperwork as I am.*

Joe has had his own middle school students experience science directly in the extended classroom. His own students have helped him get grants to study a local bayou, recording various physical and biological data.

This is a long-term study, which is transforming how his students understand both the content and process of science. It is real-world research for Joe's students, many of whom are children of fishermen, who really care what happens now and in the future to St. Andrew's Bay.

## Terrie studies algae in the TRUE program

Terrie wanted a second research experience after her first study of cogongrass with Jacqua. For several months near the end of the school year, she tried to find a project, mentor, and research site. Everything was coming up empty, until one week she had several offers, including one from the TRUE


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*About Terrie (with algae): I stayed in touch with Terrie by e-mail, and when reading her descriptive reports full of science content and the culture of science, I felt almost as if I were with her on the field trips down the St. John's River.*

*Terrie collecting algae samples.*

(Teacher Research Update Experience) program at the University of Florida[8] where she was paired with a researcher who studies algae. I stayed in touch with Terrie by e-mail, and when reading her descriptive reports full of science content and the culture of science, I felt almost as if I were with her on the field trips down the St. John's River. At the end of the summer, she provided me with a portfolio of evidence of her learning. Terrie received graduate credit in science from me as her university supervisor.

At the close of the TRUE program, Terrie gave a superb oral report to the other teachers, and she shared a song that she had written for guitar. She learned so much, and she immediately began to write for and receive research grants so her middle school students could study a local lake, using many of the scientific techniques that she learned during the TRUE program. She has involved other groups in this partnership, and now her students and others in the same grade (130 students total) go to this lake once a month with other teachers and parents. The context of her doctoral research is to study how girls in her class respond to learning science by doing science. I think she has chosen this project because she feels if she had been taught that way in middle school, she would have found her love for science much earlier in her life.

In addition, Terrie is the co-editor with me on this monograph on how engaging in scientific research has influenced K-8 teachers' understanding of science and methods of teaching science to K-8 students. In the third summer, she helped me edit the chapters in this monograph. She interviewed four of the other teachers, some of them at their research sites. I interviewed the remaining two teachers.

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## Yvette studied birds

Yvette was a third-grade teacher in Miami, part of Florida State University's ProMASE (Program in Mathematics and Science Education), an off-campus graduate program in mathematics and science education. Yvette and Marcie were two of four out of a total 250 students who were chosen to be in the doctoral program, and the rest were in a master's or specialist program.

Yvette has always been interested in animals and biology, so we tried to think of a research study that would fit her interests and comply with the components of the mandated Miami-Dade County curriculum. We decided to work in partnership with the Parrot Jungle, a commercial park and rainforest that encourages involvement of the educational community.

Yvette conducted her study charting and observing the migration of birds during the first semester of the school year, so she was teaching full-time

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*About Yvette: Both were happening simultaneously—learning and teaching. The children's questions on birds made her even more observant in the rainforest. Being a learner at the same time that she was teaching made her more aware of how much there was to learn.*

while conducting science studies on weekends and after school. Yvette kept me posted with her bird sightings and their behavior by e-mail through a daily journal, and I responded with questions and comments. Yvette said:

*Yvette at Parrot Jungle.*

> *I have been thinking how I'm going to integrate this study into my classroom, and I have reasoned that the best thing would be to teach a unit on birds so that the children will be able to identify them and be aware of the nature that surrounds us here in south Florida.*

She implemented much of what she was learning while she was teaching and developed a teaching curriculum for third grade. Both were happening simultaneously—learning and teaching. The children's questions on birds made her even more observant in the rainforest. Being a learner at the same time that she was teaching made her more aware of how much there was to learn.

Yvette presented her study in a paper set at the National Association for Research in Science Teaching '98 conference, sharing her action experiments[4] that she conducted with her students and her action research in her own classroom.

Yvette is continuing scientific research studies on animals but now has focused on primates. She is doing this work at the Monkey Jungle, a non-profit facility that maintains animals in their natural habitat, and she is applying for external funding with the scientist on-site to continue research studies with her fifth-grade students. Yvette's doctoral dissertation study focuses on how female students learn collaboratively from one another.

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## Marcie focuses on learning botany

Marcie has long had an interest in gardens and has had a Life Lab garden at her school for close to a decade. Therefore, Marcie wanted to learn the content of botany from a research perspective. Her first study was at the Garden. Through a quirk of fate, I did not get to meet her research supervisor and describe our goals. Although Marcie learned science content through her readings for the project, she did not get much time with her supervising researcher. There was only one weekend during the semester to interact with her supervising researcher, and then Marcie was more of an observer of several scientists than an active participant, studying cacti in the Florida Keys. She found herself in the role of a listener rather than an active learner.

What I learned from this process as the supervising university professor is that it is critical for me to make contact and be clear as to what I want the teachers to do, what I expect of the teachers in terms of their contribution, and to listen to what the scientist expects of the teacher.

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*About Marcie: Marcie currently is bringing her learning of science into her elementary school gifted classes. She is focusing on how technology helps students learn science.*

Marcie shared her experiences at the Garden in a paper set at the 1997 meeting of the National Association for Research. In a later semester, she worked with a meteorologist, Paul Ruscher by distance learning, using computers to download weather images from the Florida EXPLORES! program. On these various experiences, Marcie commented:

> ***All that I am privileged to attempt and each part of my endeavors, varied as they might be, lead me to discover more about myself.***

*Marcie showing sunflower in her school's Life Lab garden.*

Now Marcie has started to work with the same horticulturist, Jeff Shimonski, with whom Yvette had worked at the Parrot Jungle, and she has found a project that fits her botanical interests and those of the scientist. Last summer I met with the supervising scientist at the Parrot Jungle to thank him for his work with Yvette. I was also looking ahead for other opportunities for prospective and practicing teachers and had a chance to be clear with him what we wanted for our teachers in this experience. I could see that he had many excellent ideas for research projects for teachers. Hopefully, this monograph will help others understand what we want for our teachers in this contextual learning experience.

Marcie currently is bringing her learning of science into her elementary school gifted classes. She is focusing on how technology helps students learn science.

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## Conclusions

Our results suggested that co-participation[14] and a shared discourse[9] were critical in a contextual learning experience in scientific research. Jacqua and Terrie worked as a team on the cogongrass project, collected their data together, and tried to make sense of their findings. Kathy, Yvette, Terrie, and Joe worked regularly with a group of scientists, thereby having an opportunity to make sense of science with a variety of fellow scientists. On the other hand, Lori worked with her research mentor but was considerably more isolated than other teachers and often alone in the laboratory. However, Lori did enjoy the time alone to "reflect" on what she had learned. Marcie has had several research experiences, and she learned the most when she had a community of people with whom to interact.

Having a critical discourse community was important for teachers engaged in contextual learning in scientific research. With discourse, teachers had an opportunity to practice methods of science, experience inquiry, use the language of science, both in writing and in speaking, and they came to understand the culture of science. Science became no longer abstract "facts" but a way of understanding the world. Their understandings changed with time as the teachers learned more in such settings. Teachers with research experiences had opportunities to bring similar experiences to their students.


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*Having a critical discourse community was important for teachers engaged in contextual learning in scientific research.*

*Science became no longer abstract "facts" but a way of understanding the world.*

*Another benefit of contextual learning was that it provided a way to collaborate and form partnerships with other institutions, including other universities, schools, science museums, businesses, and governmental laboratories.*

According to the TIMSS report,[13] students from the U.S. lag dramatically behind other countries in science and technology. Why? Reasons for this could be many. From these seven teachers' personal experiences and reflections, they strongly adhere to a belief that in order to learn and appreciate science, teachers and students must also have some connection to science. Contextual learning fills this void.

Teachers are not the only ones to benefit and learn from such experiences. The teachers can better understand why and how active scientific inquiry can be integrated into their own curriculum and classroom. Although it is early yet to understand the impact of the teachers' research on the K-8 students, from my visit to Yvette's classroom and from the self-reports of the teachers, their K-8 students seem to be more involved in real science than their students before the teachers' research experiences. The teachers now are getting grants to implement the inquiry ideas in their classrooms. The students are becoming active learners, asking their own questions, much as the teachers did in their own research. In turn, their students are starting to learn from participating in contextual learning situations.

Our results supported those reported recently by the Triangle Coalition for Science and Technology Education, in which Alters[1] stated that "teachers have observed changes in their own teaching practices, particularly in encouraging the skills of scientific inquiry, encouraging curiosity and openness to new ideas and data, incorporating technology, identifying and using resources outside the school, selecting and adapting curricula, and challenging students to accept and share responsibility for their own learning" (p. vi). Their results were more quantitative while ours were more qualitative, but we came to similar conclusions. Our studies complemented each other.

Another benefit of contextual learning was that it provided a way to collaborate and form partnerships with other institutions, including other universities, schools, science museums, businesses, and governmental laboratories. This type of collaboration benefited schools, teachers, and students in many ways. Such associations also influenced partner agencies as well, increasing their communication with educational institutions. One research supervisor said, "Partnerships such as this will not only make education more meaningful but make environmental stewardship a personal ethic."

All seven teachers have made presentations on their science research experience, all at science education meetings, except for Joe. Instead, Joe presented his research at a Florida State Fisheries Conference. Joe was singled out of a group of 200 scientists and recognized for an outstanding presentation on his research. Joe reflected on that experience:

> *The most impressive part of this journey was an opportunity to present findings of our work before a forum of 200 other scientists from the state of Florida. I felt intimidated at first, and [al]though it was not part of the original summer class requirement, my mentors thought it was a necessary and important part of scientific culture. I found the whole process extraordinary.*


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I think it critical that we offer opportunities for practicing science teachers to experience inquiry and the process and culture of science through active participation and use of critical discourse in scientific research. I plan to expand this community of learners to include prospective science teachers as well as practicing teachers. Other groups are now starting to address how to provide modeling of inquiry learning to prospective science teachers.[10] It requires considerable coordination, communication, and collaboration, but it is worth it in terms of what we can learn from each other and how we can help our students.

**Penny J. Gilmer**

Years Teaching: 22

Present Positions:

- Professor of Chemistry at Florida State University, biochemist and science educator
- Graduate student in science education at Curtin University of Technology in Western Australia
- Co-editor of book with Peter Taylor and Kenneth Tobin (co-major professors on second doctorate) on university science teaching, to be called *Transforming Undergraduate Science Teaching: Social Constructivist Perspectives*
- Co-editor of this monograph

*"Having the opportunity to conduct scientific research first as an undergraduate chemistry major and later as a graduate student made a lifelong difference in how I view science."*

*"I fell in love with learning in seventh grade. Now as a biochemist and science educator I am bringing my learning together as I work with K-12 teachers and university students."*

*"Immersing teachers in the culture and discourse of science can have a deep effect on how they construct and understand science and how they teach science to their students."*

*"Practicing scientists have much to learn from working with practicing and prospective K-12 teachers."*

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## Prologue

*Two teachers, Jacqua L. Ballas and Terrie L. Kielborn, spent the summer at a state park nearby to conduct a science research study,* "Teachers Can Be Scientists, Too!" *In their experience, Ms. Ballas and Ms. Kielborn assisted biologists by locating and mapping an exotic grass, cogongrass, in the Silver River State Park. Out in the field, they found collaboration to be of great assistance for navigating and gathering data. Driving through the woods, they found no street signs to give clues as to which road was which. Discovering a "sea" of cogongrass was easy to map, but single strands proved otherwise. Ms. Ballas and Ms. Kielborn learned the language of a field biologist by their interactive conversations with each other, the park rangers, and the biologists. Most of all, these two teachers discovered just how many real-life application skills it took to conduct science research. What a great discovery it was to bring back to their students!*

# Teachers Can Be Scientists, Too!

*Jacqua L. Ballas and Terrie L. Kielborn*

A yearning for scientific research

It was a blazing hot July day in Central Florida. Two teachers had been navigating the same trail for hours. Sweat poured off their faces as they carefully studied the aerial map to locate a familiar landmark. Even dressed for Florida's high temperatures and humidity and armed with Gatorade, the two teachers were miserably hot. Yet they continued driving the all-terrain vehicle through the wilderness carefully making notes in their field notebook. Finally a familiar road appeared, and the two teachers found their way back to civilization. What was the motivation to get up at the crack of dawn and spend most of the morning driving in the woods besieged by insects, heat, and rainy weather? Scientific research, of course!

*What was the motivation to get up at the crack of dawn and spend most of the morning driving in the woods besieged by insects, heat, and rainy weather? Scientific research, of course!*

In the summer of 1996, we, two middle school teachers, joined with a research biologist, one park manager, four park rangers, and two university professors to collaborate on a project to map the population of cogongrass, an exotic species, at the Silver River State Park in Ocala, Florida. The Department of Environmental Protection coordinated the project to map the cogongrass and aggressively treat it with herbicide. The teachers' role as volunteers was to conduct a study to determine by field observation the location and density of the cogongrass population within a section of the park boundaries. Existing park roads and trails were used as a quadrant system. Data were collected in the field and transferred to an aerial map. Density was based on a scale of 1 (sparse) to 3 (dense). Acreage for each density was calculated using measurements with a planometer. This information was used in the later phase of the project when herbicide spraying of the exotic grass was done.



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## Teachers as scientists

*Teachers gain a wealth of knowledge, enhanced skills, and an enlightened view of science by working with scientists.*

Why would teachers team up with scientific researchers? Many benefits have been found in forming a partnership between scientists and teachers. Scientists are often called upon to perform public service by their institutions. Partnering with a science teacher might satisfy that requirement. Science teachers and their students serve as a new audience for scientists to address and perhaps clarify the assumptions and way of thinking of scientists. Being closely involved with this new audience can serve to dispel stereotypes about what a typical scientist is like. Massell & Searles[7] write:

> *Typically, elementary students think of scientists as white males wearing laboratory coats. When children meet and work with scientists who do not fit these stereotypes, they often are as curious about the scientist as they are about the science that he or she practices.*

Scientists often gain willing workers to help in research that is especially labor-intensive. By interacting with teachers and students, scientists ultimately contribute to creating a scientifically literate younger generation that understands the need for scientific research.[5]

Teachers gain a wealth of knowledge, enhanced skills, and an enlightened view of science by working with scientists. Teachers can gain current and accurate information about scientific discoveries that can make up for the time lag between when new discoveries are made and when they are published in a textbook.[10] Teachers build confidence and skills in working with equipment, designing experiments, and communicating with scientists. Often increased contact with scientists and science institutions brings equipment and supplies within easy access to the teachers. Perhaps the most important benefit is teachers' awareness of what real scientists do. Being aware of "real" science can change teachers' view of classroom science. In a collaborative effort between New York University and Brookhaven National Laboratory, in-service teachers are placed in an internship with scientists. Program evaluators have found that this contact has made a significant difference in how teachers view science and scientists. Fraser-Abder & Leonhardt[5] state, "This program fosters a change in teaching methods. Teachers learn to let students find their own answers, make connections clearer...and discover the benefits of cooperation in science education."

## All about cogongrass

The expanding populations of cogongrass that were the focus of this study are quickly becoming a problem for many southeastern states. In fact, this exotic plant is listed as the seventh most troublesome weed worldwide.[6] Massive stands of the dense, mat-like cogon can easily be seen on the roadways throughout Louisiana, Mississippi, Alabama, South Carolina, and Florida. The luxuriant stands of yellowish-green grass are spreading into the pastures, wooded areas, and reclaimed phosphate mined areas as well as threatening some of the rare natural communities such as the sandhill. The sandhill is an ecological community comprised of three dominant species, longleaf pine, turkey oak, and wire grass, growing in a sandy, well-drained soil. Due to the fact that these areas are prime spots for development, sandhill communities are becoming increasingly rare in Florida.

*Jacqua and her daughter Steffany look at a treated population of cogongrass.*

As with many other exotic species, the accidental introduction of this species into a climate where it thrives has caused extensive problems with native vegetation. Cogongrass is native to Southeast Asia where it covers millions of acres.[4] Cogongrass escaped from Grand Bay, Alabama, in 1912, where it was used as packing material for Satsuma oranges.[6] Cogongrass was brought to Mississippi in 1921 as a possible food source for cattle. Unfortunately, the rough edges of the mature leaf and silica bodies throughout the leaf cause mammals to avoid chewing the grass.[3] In the 1940s, cogongrass was introduced in the Florida cities of Brooksville and Withlacochee. It was to be used for cattle feed and to prevent erosion. It has been spread by illegal plantings and inadvertent transportation during mowing and construction of roadways. It is classified as a Category I Type Plant.[8] Category I types of plants are species that invade and disrupt natural communities.

Certain features of the cogongrass plant make it especially hard to control. Cogongrass has a sharp, underground rhizome that can grow through the roots of other plants and accounts for its prolific ability to spread. Stands of cogongrass can produce over three tons of rhizome per acre.[2, 3] Burning has little effect on the rhizome of the cogongrass. Cogongrass fires burn more intensely than other vegetation in sandhill communities. This disruption of the fire ecology needed to maintain the biodiversity of sandhill communities is creating a problem in park management plans where large amounts of cogongrass are present.[8] The leaves have a dry, scabrous feel and silica bodies that cause grazing animals to avoid eating them. The root system is well adapted to dry habitats and is very efficient in extracting water and minerals. These factors make the cogongrass a hearty, aggressive plant that is difficult to control.

Efforts to control cogongrass have included burning, cultivation, and the administration of herbicides. Research with various herbicides have shown differing results. "Roundup" applied at three to four quarts per acre will substantially reduce cogongrass stands with multiple applications. "Arsenal" has been found to be effective but has limitations because of long-lived soil residual activity.[6]

*Teachers discover the benefits of cooperation in science education.*

Some research has shown that combining herbicide treatment with other methods has a greater effect at controlling cogongrass. Combining burning and mowing with herbicide use was found to remove dead biomass so the herbicide can be used more effectively. The timing and application of the herbicide is critical. Late fall is the best time for treatment, when plants are sending nutrients to the rhizome. You must kill the rhizome if cogon is to be

controlled.[11] Repeated treatments are necessary for eliminating cogon. First treatments are only 90-percent effective. Dead leaves do not transmit the herbicide well, so it is best to apply the herbicide to green leaves where it will reach the rhizome.

## Knowledge through constructivism

The teachers in the study often design activities that use a constructivist approach for students. Experiences are provided that allow the students to construct meaning using their prior knowledge on which to build new knowledge. As we became the students in the scientist's world, it was time for us to learn using the constructivist approach. As learners we personally constructed knowledge about our research problem. The biologist and the community of scientists facilitated this process by their using the language of science with us. On constructivism, von Glasersfeld writes, "There is no way of transferring knowledge—every knower has to build it up for himself. The cognitive organism is first and foremost an organizer who interprets experience and, by interpretation, shapes it into a structured world."[1] Everyday that we experienced the ups and downs of field work, we organized and interpreted our experience in a field biologist's world.

*Having constant communication between the teachers and the biologist allowed the scientists to feel confident about the work being done.*

Jacqua had previously worked with field biologists at the Apalachicola National Estuarine Research Reserve during a summer course for her master's degree through the Science FEAT program. Terrie had contact with scientists at NASA through a teacher education program called NASA Educational Workshop for Elementary School Teachers (NEWEST), but she had not experienced research field studies previously. With these prior experiences, we began to make new connections based on the cogongrass field study. Working as a team allowed us to socially construct much of the meaning as we researched in the field and came to shared understandings. When confronted with a problem, such as identifying an unknown grass, we would share our knowledge to solve the problem. Comparing our individual constructions about cogongrass gave us more confidence in what we were learning. Jacqua and Terrie both kept journals of reflections from each outing in the field. Jacqua reflected about her experiences at the Reserve and how it compared to the present study.

(Excerpt from Jacqua's journal):

> *A difference between this research and the Apalachicola work is that we have to plan and work out problems on our own. At the [Apalachicola] reserve, the biologists were with us and listened to our input, but they made the decisions about how to proceed. In this work, Terrie and I adjust on our own. Rosie [the park biologist] is just a phone call or e-mail away for major questions, but we handle many things in the field. This makes us feel much more a part of the community of scientists.*

Throughout the summer, we had many opportunities to construct new meanings, reflect on them, and grow in our understandings. We experienced the constructivist environment that we try to provide for our students. Throughout the study of cogongrass, we viewed the knowledge gained through this constructivist lens.


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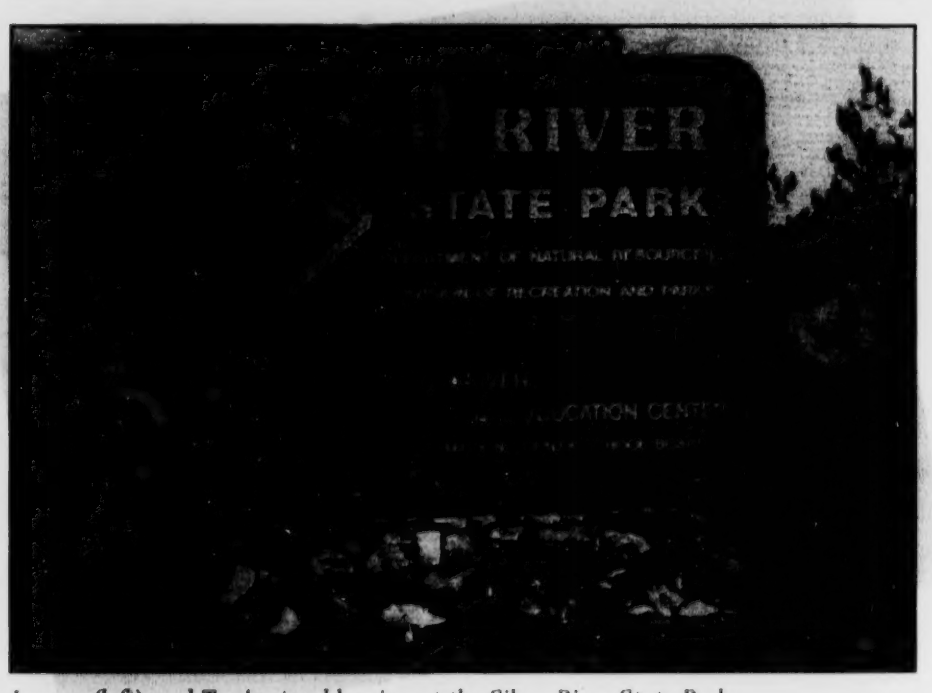
## Mapping the cogongrass

There were many reasons why this research project was so appealing to the teacher team. The first and foremost reason was the opportunity to conduct "real" science for a "real" purpose. It was evident that the work we would be doing was necessary and useful in the project designed by biologist Rosie Mulholland. Second, the research project was done at the Silver River State Park within a short drive of our homes. By conducting local research, we could stay close to our families, rather than commuting to a university or laboratory in a distant city. This close proximity allowed us the flexibility to set our own schedules around the demands and constraints of our personal lives. Being close allowed us to work when the weather conditions were favorable and visit the park several times a week. We were also more aware of the problems of this exotic grass, as the cogongrass is easily seen at many locations throughout the county. Our students have the opportunity to visit the park as part of their fourth- and seventh-grade science curriculum and have access to the park on weekends when it is open to the public. A third reason was to obtain graduate credit toward a doctoral degree in science education. With the support and tutelage of the university professors, Dr. Dana Griffin at the University of Florida, Dr. Penny J. Gilmer at Florida State University, and the research biologist, Rosie Mulholland, we were able to not only learn a tremendous amount about the project but receive graduate course credit at the same time. Finally, it allowed us to work together as colleagues. As teachers at the same school, we often had opportunities to collaborate in ways such as writing grants, preparing for workshops, and designing a pre-service science education course. Now we had the opportunity to do scientific field research. We were both thrilled with the opportunity to learn new things.

## Silver River State Park, our field site




*Jacqua (left) and Terrie stand by sign at the Silver River State Park.*

*Our journals became first-hand, real science stories to link the students to real world applications as we teach these scientific processes.*

The location of the project was the Silver River State Park which consists of 4,432 acres of beautiful natural habitats including the pristine Silver River and three miles of the Oklawaha River. The park is named for its most outstanding feature, the Silver River, which is fed by the largest artesian spring in Florida with a flow of 530-million gallons of water per day.[9]

The park has recently been opened for public use, and a park management plan has been completed. Plans include recreational activities such as interpretive hiking trails, picnicking, horseback riding, swimming, and primitive camping. Natural communities found in the park include species that require different amounts of moisture. For instance, *xeric* means needing minimal amounts of moisture, while *mesic* needs more moisture, and *hydric* needs the most moisture. The species in this park include mesic flatwoods, sandhill, scrub, scrubby flatwoods, upland hardwood, mixed forests, xeric hammock, depression march, floodplain forest, swamp, hydric hammock, and wet flatwoods. The natural community most severely affected by the invasion of cogongrass was the sandhill community. These open area communities with dry, sandy soil are characterized by long leaf pine, turkey oak, and wire grass plant species. This community is adapted to and maintained by periodic slow-burning fires. The presence of cogongrass disrupts the normal fire ecology because the grass burns so hot and fast. Crowding out the native wire grass also eliminates a food source for animals found there. Species such as the gopher tortoise, Sherman's fox squirrel, and the indigo snake depend on the sandhill for their survival.

## The project unfolds

In order to manage and maintain the biodiversity within the sandhill areas of the Silver River State Park, it was necessary to plan an extensive effort to eliminate the exotic cogongrass species, *Imperata cylindrica*. Current estimates before our study showed that cogongrass had invaded over 50 acres of sandhill community in the park. A grant written by a biologist, Rosie Mulholland, from the Department of Environmental Protection with the goal of eliminating as much cogongrass from the sandhill as possible was funded for $31,000. Other objectives of the grant were to reduce the biomass of cogongrass at Silver River State Park by 80 percent, control the expansion of cogongrass by herbicide treatment, and encourage the re-establishment of native herbaceous ground cover.

Project plans included mapping the current population of cogongrass, conducting a concentrated effort of herbicide spraying during September, October, and November of 1996, and treating any regrowth in the spring. Replanting native vegetation may prove necessary to restore the natural balance of the community.

In order to launch a successful herbicide application, it was necessary to have an accurate and up-to-date map showing location and density of the cogongrass. This part of the study was carried out by the volunteer teacher team. The mapping project began in July 1996.

## Our mapping technique

A plan outlining mapping techniques and procedures was discussed at an initial meeting with the volunteers and the principal researcher, Rosie Mulholland. The team decided to use a map developed by Bob Simons, a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*Terrie and Jacqua get ready to board "The Mule."*

biologist with the Department of Environmental Protection, which divided the park into sections based on existing roads and trails. An aerial map was laminated and used to record the areas of cogon population by drawing in the areas with three different colors to designate the three densities. We were also instructed how to use the planometer, a device to determine acreage. Instruction was given to show how to convert the planometer reading to acreage.

The volunteer teachers navigated each section on the map and used ocular measurements to record the amount of cogongrass in the plot. Some large quadrants required hiking into the quadrant to determine the growth pattern of the cogongrass. We did most of the mapping as we drove an all-terrain vehicle around the perimeter of the section. The park service provided us with a vehicle for use during this project. Data for each section were recorded in a field log, as well as any wildlife observations.

We determined the density of the grass using a scale from 1 to 3: 1 being sparse, 2 being medium, and 3 being dense. Sparse was defined as covering less than 25 percent of a unit area, medium was 25-90 percent, and dense was 90-100 percent coverage. Once we mapped a section, we transferred the data to a laminated aerial map. Sections of areas already treated with a herbicide were also mapped. The coded map provided information on how much herbicide to purchase for the fall spraying and made the areas to be treated easy to locate. By making an overlay of the population areas, treatment of any re-growth can be easily and efficiently accomplished and recorded. Since aggressive re-treatment is necessary for the successful removal of this exotic, the coded map has been a valuable resource to the park personnel who are completing the project.

In order to calculate the total acreage of the density of cogongrass, we used a planometer to measure each section and its density. The displayed reading of the planometer was converted to acreage using a formula specifically calculated for a map scale of 1 inch = 400 inches.

Out of a total of 106 acres of the park which contained cogongrass, the total acreage calculated for density one was 20.7 acres, density two was 26.3 acres, and density three was 58.5 acres. The pretreated area totaled 14.5 acres. The actual acreage of cogongrass calculated from the mapping study proved to be a much larger amount than originally estimated.

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## Reflections of the summer study

The summer research project proved to be a very beneficial venture for the park biologist, the park manager, the university scientists, and the teachers. The park biologist noted in conversations and letters how valuable the volunteer hours were for the study. During the project, over 70 hours of volunteer time was logged by each teacher. These hours of work would have been difficult for the park staff to schedule around their many other duties.

The teachers worked within the parameters set by the park manager so that safety rules were followed and care was taken of the loaned equipment. Many of the typical skills that teachers employ surprised the biologists. For example, we suggested laminating the aerial maps and using permanent markers to draw in the cogongrass population areas. Soon we had several maps to laminate for the biologist and park manager!

*Later, Rosie consulted us about the same areas on the map where small packets of cogongrass existed. She commented that we were the "experts" on locating cogon!*

Having a constant communication between the teachers and the biologist allowed the scientists to feel confident about the work being done. Regular e-mail and phone conversations helped with direction in the study. If a question arose regarding the identification of a plant or how to proceed with the study, we were not afraid to ask. This relationship of respect between the scientist and the teachers was integral to the success of the project. Terrie noted in her journal reflections about the study how informative the biologist, Rosie Mulholland, was in showing how to use the planometer and recording populations on an aerial map at the beginning of the study. Treating the teachers as colleagues served to put the project in a partnership role. Respecting our background as science teachers, Rosie taught us the language of a field biologist. Soon we were communicating with the same vocabulary.

The teachers learned many new skills while mapping the park. Reading aerial maps and schematic maps of the quadrants was critical to finding our way through the park. On many days, we would comment on how much geography there was to science! Our navigation and orienteering skills certainly improved. We learned how to use new scientific instruments such as the planometer. Another skill that was sharpened for the teachers was in collecting and recording data. We found it was necessary to record data, such as making notes about areas to continue mapping, what sections were completed, and plans for the next day while these thoughts were fresh in

*Jacqua and Steffany look at a treated cogongrass.*



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our minds from the field work. If not recorded immediately, it was easy to forget. In recording the data, we sharpened our mathematical skills of estimating, reasoning, critical thinking, problem-solving, ratio, proportion, and graphing skills. We used writing skills every day as we recorded our thoughts, wildlife observations, ideas, and frustrations in the research journals and field logs. These written artifacts were referred to and used extensively throughout the project. All of these skills are things we teach our students. Now we have first-hand, real-science stories to link the students to real-world applications as we teach these science processes. We have the experience on which to base conversations with our students. The research experience made us both think of more ways to provide this learning base for our students. We discussed more ways to set up these opportunities for our students, perhaps using the schoolyard as a mapping exercise. President Clinton advocates setting up learning opportunities for students to use their skills. Our research experience gave us many examples of science learning to share with our students.

*Knowing the scientific facts is just the start in scientific research.*

Perhaps the most valuable skill gained from the study was the importance of teamwork. Both teachers noted many examples from their research journals which highlighted how important it was to work together. Not only did we feel part of a planning team with the biologist and the park manager, but we functioned well as a team together. One teacher would drive the vehicle, and the other teacher would navigate, record field notes, and manage the maps. On a few occasions, each teacher experienced trying to work independently and found it to be very difficult.

(Excerpt from Terrie's journal):

> *It was necessary to work as a team for many reasons such as to not get lost, to have four eyes available when looking for landmarks, to discuss and judge various density levels of cogongrass, to discuss strategies for solving problems, situations, or dilemmas, for safety in the woods, and for encouragement and support.*

(Excerpt from Jacqua's journal):

> *It is comforting to have another person there to bounce ideas off and help in making decisions about whether or not a grass is cogon or one of the other grasses that constantly trick us.*

Accomplishing the project through teamwork was a constant theme in discussions and writings about this study.

The work at Silver River State Park has given the teachers many new ideas about involving students in ecological studies. In daily conversations in the field, we discussed ways to use the properties around our school to study exotics. The middle school where we teach borders the state greenway property, where many stands of cogongrass exist. Monitoring those populations could be a future project for our students. Through conversations with the teachers, a high school student, Erin, became interested in doing a follow-up study on the cogongrass at Silver River State Park. She is doing a plot case study to see if three different pre-treatments of the areas before the administration of herbicide will affect the re-growth of cogongrass. She has three plots to monitor: one that was burned, one that was mowed, and

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one that was mowed and burned. The teachers met with her, shared their mapping study, and partnered her with the park biologist as a mentor.

Overall, the summer study has led to a new understanding of the processes of science and scientific research. Knowing the scientific facts is just a start in scientific research. For many teachers, this is where science ends. From our experience in the field, we know a much deeper story about how scientists work together to design studies, conduct field research, collaborate, and communicate.

(Excerpt from Jacqua's journal):

> *This study has made me realize the importance of teamwork in science, problems in field research, and the difficulties of dealing with exotic species. It was powerful in the connections to real science and real data collection. I feel I have a much more mature vision of what real science research is like. This is an awesome tool for a science teacher!*

This knowledge has changed the way we think about science and how we share science with our students.

*A version of this paper was presented at the National Association for Research in Science Teaching Conference at Oak Brook, Illinois, March 23, 1997.*

*Terrie looks at a treated cogongrass population with a past density of 5.*

**Terrie L. Kielborn**

Years Teaching: 20

Present Positions:

- 6th-grade middle school science teacher at Belleview Middle School, Belleview, FL
- Adjunct professor for National Louis University in Instruction and Curriculum
- Part-time instructor for science and mathematics methods courses for Florida Southern College
- Graduate student in science education at Florida State University
- Co-editor of this monograph

*"I love being a scientist! Think I'll make a banner that says this and post it on one of my classroom walls."*



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**Jacqua L. Ballas**

Years Teaching: 18

Present Positions:

- 7th-grade middle school science teacher for Belleview Middle School, Belleview, FL
- Graduate student in science education and educational leadership at Florida State University

*"Perhaps the most valuable skill gained from the study was the importance of teamwork. Both teachers noted many examples from their research journals that highlighted how important it was to work together."*

*"I feel I have a much more mature vision of what real science research is like. This experience is an awesome tool for a science teacher."*

*"Every day that we experienced the ups and downs of field work, we were organizing and interpreting our experience in a field biologist's world."*

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## Chapter Three

Prologue

*How crabs adapt to salinity instigated the study,* "How a Crab's Sense of Smell Changes the Life of a Teacher" *by Kathleen Foley. Through her observations of the inner antennae of various crab species, Ms. Foley learned the language of marine science and how to safely collect marine species. She used technology to learn and document her research. She made two important discoveries: She found that mistakes can be powerful to the learning process, and that there are more questions than answers in science. She was encouraged to ask questions because the scientists themselves had many questions to ask. As the scientists at the laboratory would share investigations with Ms. Foley, she, in turn, would share these investigations with her middle school students. In her own words, "The experience has changed me forever, which is what we should strive for in our teacher preparation programs and classrooms."*

# How a Crab's Sense of Smell Changes the Life of a Teacher

*Kathleen R. Foley*

Teacher engaged in scientific research

My research project on "Crustacean Olfactory Systems: A Study of Morphological Adaptations to Salinity" began in May 1996. I worked at The Whitney Laboratory in St. Johns County, Florida, part of the University of Florida, with a research scientist named Dr. Richard Gleeson. Our objective was to study the olfaction system, which controls the way the crab smells. I was to videotape crustaceans and compare the antennules, which house the olfaction system, using different types of microscopes. The apparatus that the male and female crab uses to smell is called the aesthetascs—pronounced "ask-the-task." The crustaceans studied included the mud crab, the spiny crab, the striped hermit crab, the mudfiddler crab, two types of sand fiddler crabs, and the blue crab. My job was to learn and compare the antennules of these crustaceans by their placement, arrangement, number, size, and length of the aesthetasc, insertion point of the aesthetasc in the head, and the waving action of the antennule.

*A powerful learning experience*

The results of the project include the impact of the research on the teacher, including the technical skills developed as well as the knowledge of community resources and of crustacean sexual biology and morphology. I had many rich conversations with scientists who promoted the use of research in the classroom by providing methods of obtaining animals, management of the animals, and projects for study by the students. I have used several of these suggestions during the school year in my classroom with limited success at one school and more success at a new school.

During the summer of 1994 at Florida State University in Tallahassee, Florida, as part of a master's degree program in science education funded by the NSF in a program called Science FEAT (Science for Early Adolescence Teachers),[6] I worked with a research scientist in a chemistry laboratory

*I have discovered that employing these methods of learning science, by actually doing scientific research, is the most powerful learning strategy I have experienced.*

synthesizing new compounds and testing their oxidation-reduction behavior by cyclic voltammetry. This experience has proved to be a powerful learning experience, which has had a profound impact on me as a teacher, a person, and my classroom and teaching practice.

Thus, during the summer of 1996, while enrolled in a doctoral program at Florida State University, I had the opportunity to work again with another research scientist. This time I conducted research with a scientist who works near the middle school in which I teach. Working close to home, I found I could continue these opportunities for collaboration, obtaining biological samples for classwork, and meeting with research scientists. Additionally, the possibilities for future contact by my students with The Whitney Laboratory is possible because of its close proximity.

The results of that project were initially presented at the annual meeting of the National Association for Research in Science Teaching and are presented here. The method of study I employed is contextual learning.[1] This is a method of learning science by immersion in the culture and practice of science in which the science experience is taking place. Both of these experiences, with Science FEAT and Dr. Gleeson, have empowered me as teacher. I have discovered that employing these methods of learning science, by actually doing scientific research, is the most powerful learning strategy I have experienced. It is my hope, as I express how powerful this learning is, I will influence those of you who are involved with teacher preparation or teacher enhancement at the university level.

*Kathy looks over the whole blue crab.*

*Kathy and Chuck Bowling from the F.S.U. Biology Department discuss the blue crab.*

*Kathy avoids the blue crab's bite.*

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*Learning using prior knowledge*

I believe that "learning is defined as the construction of knowledge by individuals as sensory data that are given meaning in terms of prior knowledge."[8] Our students are not empty vessels. They bring their experiences with them into the classroom, and, in this sense, this is prior knowledge. I provide them with the opportunities for experiences; then they can bring this knowledge forth into their relevant minds at this time. Constructivists focus on prior knowledge, stating our students are not blank slates but have a base of knowledge they have constructed from their own community. Our language is developed through years of living in an environment and through practice and struggle. The opportunities that we provide for exploration and discussion in our classrooms should afford students opportunities for both successes and failures. Ernst von Glasersfeld[2] emphasizes that we need to step back from guiding our students on the right path and provide them with many paths, so that they can experience some failures or mistakes as well as the sweet successes. Many scientists have experienced failure on the path of learning and discovery, and it is important to remember that we can learn powerfully from our mistakes. By providing opportunities for my students to experience learning in the natural environment, they can construct knowledge through sensory data. Mistakes are necessary for new constructions in learning.

*The opportunities that we provide for exploration and discussion in our classrooms afford students opportunities for successes and failures*

*Learning through my new experiences*

Dr. Gleeson's research is on the olfactory system (i.e., connected with the sense of smell) of the male blue crab, *Callinectes sapidus*. Dr. Gleeson is one of an elite group of scientists who study the olfactory system of this species.[3-5] The aesthetasc (part of the olfactory system) sensilla of the blue crab is highly specialized, enabling the blue crab to go from areas of high salt (or salinity) to very low salinity.[5] This is very important to the blue crab because they only mate once in their three-to-four-year lifetime.

In many crustaceans the mating is synchronized with the molting. All arthropods shed their hard outer skin—or, in the case of the blue crab, it is their exoskeleton. The sense of smell is important because during the final molt of maturity, the females emit a chemical signal (i.e., a pheromone), which is present in the urine. The male detects this pheromone by small chemosensory hairs (called aesthetascs) that are located on the small, inner pair of antennae. This signal triggers a specific courtship behavior in the male. After the molting and mating occurs in low salinity waters, the female crab migrates towards the mouth of the estuary, which is very high salinity. The outer dendritic segment housing the aesthetasc becomes very short in fresh water, and the opposite is true. Dr. Gleeson suggests that this reflects the effective distance over which an appropriate osmotic/ionic microenvironment for neural function can be maintained within the aesthetasc. Blue crabs have the ability to adjust to extreme salinity changes in water.

My project was to compare and videotape the antennules of a variety of species of crustaceans. The crustaceans included the mud crab, *Panopius herbstii*; the spiny crab, *Portuneus spinicarpus*; the striped hermit crab, *Clibinarius vitattus*; the mud fiddler crab, *Uca pugnax*; two sand fiddler crabs, *Uca pugilator* and *Uca rapax*; and the blue crab, *Callinectes sapidus*. I received training on the use of several pieces of equipment and on how to safely collect the specimens. I recorded data in a laboratory notebook, videotaped the crabs, and recorded personal reflections of my learning in a journal.


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*The simple magnificence of observing these animals left me feeling in awe.*

I used a dissecting microscope to observe and to draw the antennules. I found the nose simply beautiful. The simple magnificence of observing these animals left me feeling in awe. The chromatophores (i.e., color pigment cells) are radiant. I was thrilled to be able to spend so much time looking at a simple animal in very great detail with the aid of technology. I find that my students are often excited at the color and shape of objects that we discover in class. During this project, I felt the enthusiasm that I so often hear in their voices in my laboratory. The next step was to cut off the antennule and prepare a wet mounted slide. Then, I used the light microscope fitted with DIC (i.e., differential interference contrast) to observe the very small hair-like structures. I made several measurements and did the videotaping at this time. Finally, I looked at a live specimen under a macro photographic lens, making observations about the waving of their antennules in the water. I videotaped the action at this time. The waving of the antennules correlates to our sniffing the air when we detect an odor. On several occasions, I went to the estuary to collect specimens, which was powerful because it provided me with another view of the animal in its natural environment. The opportunity for students to collect specimens or samples from the natural environment is valuable to increase their level of learning and provide sensory data.

*The dissecting microscope gives another view.*

*Learning through my mistakes*

I learned that the language of science can be difficult, such as the Latin pronunciation of the crabs. As I investigated these crabs, I made many mistakes in pronunciation. I recall another time I made a mistake and learned from it was the first time I dissected an antennule from the blue crab, spent all day looking at it, drawing it, commenting on it, and then, before leaving for the day, I asked Dr. Gleeson if he wanted to take a look. At that time he informed me I was looking at the outer antennule, not the inner antennule which houses the aesthetasc. From this setback, I felt both discouraged and empowered. I was discouraged because of the enormous task that seemed to lie ahead of me and the fact that I had just spent many hours looking through a microscope at the wrong thing. Only later as I came to appreciate the value of making this mistake did I feel empowered. I know how my students must feel when they are looking at the wrong thing and how much easier it would be for me to check their struggles early and avoid the cries for assistance. However, I know first-hand the power of making a mistake and how one's learning curve moves beyond what was known when the discovery is found. I found that my powers of observation have increased immensely, and I have learned more patience.

*Look at those beautiful chromatophors.*

*Mistakes are necessary for new constructions in learning.*

Another learning experience occurred during the first editing of the videotape, which I did alone, and it contained errors because my cataloging of the animals was not thorough enough. After that I worked with Dr. Gleeson in the laboratory, making the corrections and final copy. The mistakes were powerful in the learning, due to the knowledge gained and the opportunity for further communications.[9] I share these mistakes with my students. My

*I found that my powers of observation have increased immensely, and I have learned more patience.*

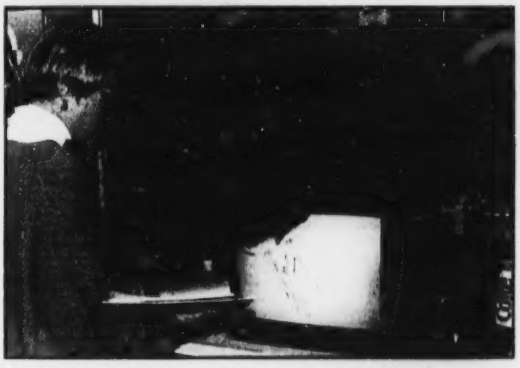
students used to picture science as an errorless discipline, and these mistakes expose my students to the evolving process and nature of science.

The gathering and analysis of data occurred simultaneously. The laboratory notebook provided opportunities for documenting my observations and devising a method for coding. Miles and Huberman[6, p. 55] explain, "Codes are efficient data-labeling and data-retrieval devices. They empower and speed up analysis." My keeping accurate records of the crustaceans as I recorded them for the editing of the videotape proved to be a tremendously important job.

## The culmination of my learning

The project was a powerful learning experience for many reasons. I was proud of the confidence I gained to ask questions about other scientists' projects. I learned much of the biochemistry involved in the crustaceans' breathing, and this knowledge encouraged me to ask more questions. Dr. Gleeson was a powerful example by saying to the many questions I asked that, "Scientists have many more questions than answers." The technical skills which I obtained working with the crustaceans were many and varied. I found the scientists to be ingenious, building specific equipment to meet the needs of their project. I enjoy this type of problem-solving, and I now have many competencies in this area. This aspect was challenging and helpful for my classroom because I constantly have to fix or build something specific for a class project with my students' help.

*The dissecting microscope allows the crab to be viewed while in its habitat.*



*Kathy with Richard Gleeson, reviewing her script and editing live footage of videotape.*

*Viewing the crab in saltwater allows the movement of the aesthetasc to remain visible.*

The editing of the videotape was a source of much learning and frustration. The original videotape was two hours long, and it took 19 hours to edit it down to ten minutes. Dr. Gleeson and I picked the segments of videotape by looking at my script and thinking about the audience. We wanted to include many views where the measurement bar would be visible to the viewer. There was an abundance of live footage, and we wanted to get the most perfect views. I also gained more information regarding community resources and made more friends from colleagues.

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## Bringing new ideas to my classroom

The quality of investigation has helped me as a classroom teacher because I discovered more of the ease with which specific investigations can be conducted. In the laboratory, I met several interesting researchers and scientists with whom I had many powerful conversations about the education process. Their ideas about the ease with which I can obtain specimens from the field to bring into the classroom were inspiring. They shared several very simple, interesting investigations with me that incorporated problem-solving and discovery that have proven to be a valuable learning experience for my students.



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*While teaching the same summer as the research experience*

Additionally, the quality of my teaching improved during that same summer. At the time of the project, I was teaching marine science. I was in the intracoastal waterway each week with middle school students collecting plankton. I had a different group of 12 students every two days. We would wade through the water about chest high, dragging our nets behind us. Upon getting out of the water, we would walk through a bird sanctuary, and I would point out the crab burrows, and this would begin a nice discussion. Students would often catch hermit crabs, and we would sit on the beach having great discussions about the animals in the area. It became a perfect teachable moment, addressing the questions at hand, and giving them life-saving information about the water currents in the area. We would explore the barnacles on the pylons and have a discussion about the sense of smell and its importance to the barnacle population. Barnacles will only inhabit areas where other barnacles are, and they locate these areas by the sense of smell. Most of what I was teaching this summer I learned through the readings at The Whitney Laboratory and the discussions with other scientists, teachers, and, of course, my students, who always provide me with lots of information.

*While teaching one year later at a traditional school*

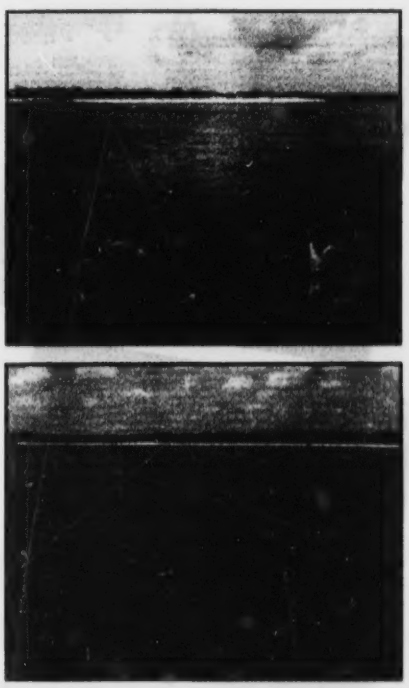
The problem I experienced during the school year immediately following the research experience was providing an opportunity for an affordable Marine Science Program and the contextual learning experience that I had at The Whitney Laboratory. It left me terribly frustrated because I wanted to offer this type of learning to my own students. I feel science should be learned through the concept of contextual learning, and all instruction should be in a setting such as my experience with Marine Science. Anything less remains marginally effective for me and my students. The experience has changed me forever, which is what we should strive for in our teacher preparation and classrooms.

*Moving to a more progressive school*

I transferred to a different middle school in the following year. There I was able to use several of the discoveries I had made in the field and apply them to my own classroom, setting up laboratories where the opportunity for questioning is well established. However, many schools will not allow this type of experience to take place. My dilemma is to find ways for my students to become lifelong learners, to experience the joys, triumphs, and disappointments of scientific discovery.

*My dilemma is to find ways for my students to become lifelong learners, to experience the joys, triumphs, and disappointments of scientific discovery.*

The new setting had a great impact on my teaching and the quality of the laboratories in which I immersed my students. This new setting is much more supportive of the quality experiences that must take place while using the model of contextual learning. I feel that my teaching practice is more effective, and the students have many more opportunities when they are conducting field studies in the local estuary.



*Kathy with her middle school students in the Matanzas Inlet.*



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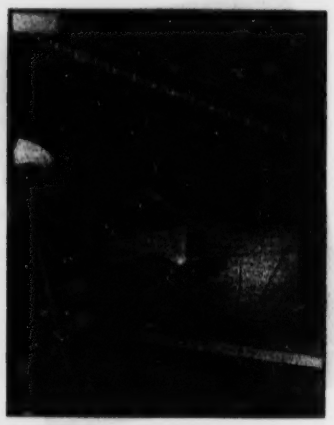

*Kathy examining the crab's asthetasc on videotape.*

**Kathy R. Foley**

Years Teaching: 9

Present Positions:

- Sabbatical leave from usual job as middle school science teacher
- Teacher of science methods courses for University of North Florida
- Part-time curriculum specialist at the National High Magnetic Field Laboratory
- Doctoral candidate in science education at Florida State University

*"I guess the most significant thing that ever happened was my mentoring scientist telling me that science has many more questions than it has answers."*

*"We would wade through the water about chest high, dragging our nets behind us. Students would catch hermit crabs, and we would sit on the beach having a great discussion. It became the perfect teachable moment, addressing the questions at hand."*

*"The experience has changed me forever, which is what we should strive for in our teacher preparation and classrooms."*

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*What fun! Teaching should be like this!*

SSEY CE

## Prologue

*Lori Livingston Hahn experiences contextual learning through her study, "Investigating Fish Mortality: A Science Teacher's Learning Experience." Her research study investigated the cause of death in fish by looking at algal toxins. She learned one of the realities of authentic science—that sometimes answers are not found. As in many scientific studies, Ms. Hahn found that further research was needed. She not only experienced the rigor of governmental procedures but also was able to immerse herself in the culture and language of science. Unlike some teacher programs where the teacher is merely an observer, Ms. Hahn was able to work directly with a scientist. She constructed meaning on chemical processes through active involvement. As a result of her experience, she has produced a collection of lessons to use with her middle school students on marine toxins. She strongly feels that the collaboration between scientists and teachers will provide rich learning experiences for both.*

# Investigating Fish Mortality: A Science Teacher's Learning Experience

*Lori Livingston Hahn*

## A rewarding and enriching experience

"Teacher as learner" can be an effective metaphor in the classroom if the teacher is comfortable with and assumes the role of facilitator and co-learner rather than dispenser of facts and information. There are other such learning opportunities in which teachers can be found during their careers, as well. These include graduate-level coursework, practicing teacher workshops, and other traditional modes of learning.

*Working concurrently with a research scientist offers the teacher a first-hand glimpse of the culture and language of science and a chance to immerse oneself in an actual scientific investigation.*

However, one of the most rewarding and enriching experiences in which a science teacher can be placed is that of a contextual learning situation. This experience provides the teacher with direct contact with a professional in a scientific field. Working concurrently with a research scientist offers the teacher a first-hand glimpse of the culture and language of science and a chance to immerse oneself in an actual scientific investigation. In choosing an area that is meaningful to the teacher—in this teacher's case, environmental research—the teacher is capable of learning a great deal through an experiential approach. Once back in the classroom, the teacher can use personal research findings rather than be limited to the examples in the textbook. Students are far more likely to listen to one's experiences than mere facts and information. The old adage, "experience is the best teacher," certainly holds true for contextual learning. After becoming acquainted with this type of learning, the teacher can then extrapolate similar learning situations to his/her own classroom by providing contextual learning experiences for his/her students.



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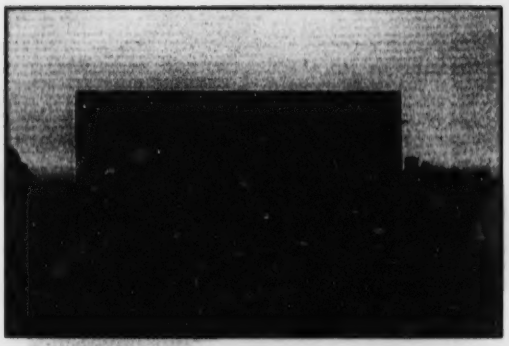
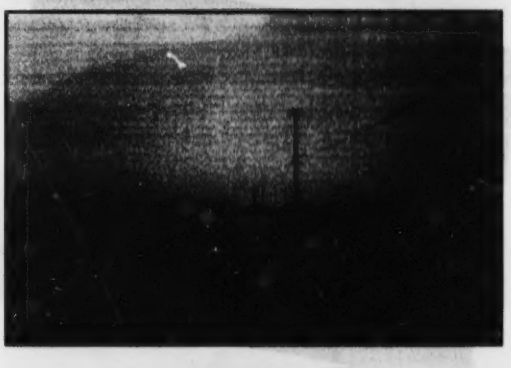
## My EPA journey begins

To satisfy a science research requirement for a doctoral program in Science Education, I volunteered at the Gulf Ecology Division of the Environmental Protection Agency (EPA) during the summer of 1996. I chose this agency because of my interest in the environment, paralleled with a desire to learn more about biochemistry. The researcher who offered to serve as my research mentor was a biochemist with an interest in toxicology. His own background included some early teaching experience. This was a major factor in his interest in assisting me with my own career goals. He began his career as a chemistry teacher in a private academy and, after completing his Ph.D., sought a position at the university level. However, through a few twists of fate, he ended up at the Environmental Protection Agency and has worked there for the last 25 years. He is very concerned with the status of science education in the U.S., as he has a 15-year-old daughter who plans to pursue a career in medicine.





*(Top) Sign at the entrance to the EPA Lab.*

*(Middle) The long road.*

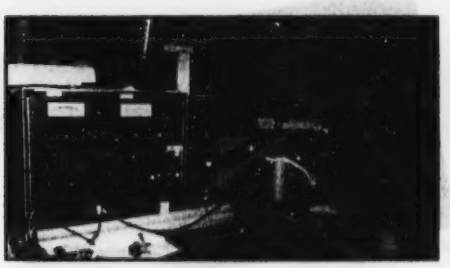
*(Bottom) Lori and Terrie on front steps of EPA Lab administration building.*

Prior to this research, I was involved with a contextual learning experience in archaeology as part of my master's degree in Science Education. While archaeological research was not my first choice, I was placed there due to my pregnancy. This placement was more conducive to my physical condition than field work or laboratory experience. Much to my surprise, I enjoyed the experience and learned a great deal about a previously unfamiliar subject. However, I still longed for a research experience related to environmental science. This opportunity ensued during the first summer of my doctoral studies.

## Fish mortality

The purpose of this investigation was to establish a method and determine the cause of mortality in a fish kill. This particular study involved using livers from hardhead catfish (*Arius felis*), which were collected from a fish mortality in central Florida. The cause of death had not been determined, but an algal toxin was suspected.

The technique known in most scientific jargon as HPLC, the acronym for high-performance liquid chromatography, was the method we chose for this study.[6] The name *high-pressure liquid chromatography* is also used for this procedure. HPLC is an analytical separation method. By analytical, I mean that the results are analyzed quantitatively. Prior to this research, I had used only a simple qualitative method of separation called paper chromatography, using coffee filters in my classroom.



*Fluorometer equipment in EPA Lab.*

*EPA Lab.*

The term *chromatography* designates those processes that allow the resolution of solute mixtures by selective fixation and liberation of dissolved components by passing a liquid phase containing the components over a solid support. In simple language, HPLC allows components of a sample to be separated. The information obtained is used for the identification, determination, and quantification of the sample components. The results are then compared to a standard to aid in the identification of a suspected component—in this case, the algal toxin, microcystin.

Our samples consisted of the tissues of the catfish livers combined with several organic solvents, used to break down the cells of the liver tissue. This cell lysis, or cell breakdown, of the sample yielded a liquified sample, which was placed in the HPLC system to determine the presence or absence of the suspected algal toxin, microcystin.[12] These samples were compared to a standard of microcystin. An identical or similar UV, or ultraviolet peak to the microcystin standard, would indicate that the catfish had been infected with this algal toxin. This could then be considered as a possible cause of the fish mortality.

Lori using lab equipment.

learning about algae

Toxic blue-green algae (i.e., cyanobacteria) are agents of certain water-based toxicoses. Water blooms, or dense surface scums, caused by eutrophication, occur for a few days, weeks, or months when the temperature, nutrient levels, and stratification status are ambient. During these algal blooms, the concentration of these toxins reach such high levels that any animal can ingest an acutely lethal dose. These algal toxins are a potent promoter of liver tumors.[2] Using certain laboratory procedures, such as HPLC, the presence of these toxins can easily be detected in the water or in the livers of the fish. Due to a worldwide rise in pollution and, hence, eutrophication, there is a also a rise in algal blooms.

*Lori and Dr. P. Schoor work at EPA lab.*

*Microcystin* is the term given to the fast death factor produced by *Microcystis aeruginosa*, a type of freshwater algae.[3] This is a type of cyanobacteria, a member of the division *cynanophyta*, or blue-green algae. They are classified as *hepatotoxins*, as the liver has always been reported as the organ showing the greatest degree of histopathological change when animals are poisoned by cyclic peptides. Microcystin is a heptapeptide. The molecular basis of action for these cyclic peptides is not yet understood.

It was just interesting to know the procedure even though our hypothesis was not correct

This leads to the research that Dr. Schoor is currently pursuing. His hypothesis is concerned with whether or not marine toxins induce an enzyme called NOS (nitric oxide synthase) in fish. The three scientists who originally discovered the NOS enzyme received the Nobel prize in medicine in 1998. Thus far, Dr. Schoor has not proven that marine toxins induce NOS.

How the research was done on the catfish

To quantitate the presence of a particular microcystin called MC-LR in tissue, a sample of catfish liver was homogenized in methanol. This solution was placed in a sonicator, which is an instrument I termed the "milk shake maker" because of its appearance. This "milk shake maker" breaks down the cells in suspension. The cell suspension remains in the sonicator for several minutes to break down the tissues and promote cell lysis by breaking down the proteins in order to move the liver tissue and its contents into solution. The soluble top layer was separated by high-speed centrifugation. The precipitate was then re-extracted with methanol, and the combined methanol/water extracts were extracted three times with hexane before a final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evaporation to reduce the volume. No further cleanup was performed before injection to the HPLC unit.

## The mystery of our fish mortality remains

I did two complete runs of 11 samples each to determine the presence of microcystin in the catfish livers. The data clearly showed that there was no microcystin present in the livers, as revealed by spectral comparison and retention time of the microcystin standard. The cause of death for the catfish remains unsolved.

HPLC is a useful method to determine the presence or absence of algal toxins in the livers of fish. This particularly study, however, failed to reveal the cause of death in this particular fish mortality.

## Comparing parallels of scientists and teachers

As with many professions, teaching included, there is an abundance of paperwork and governmental procedures that cloud the excitement of learning. Research scientists are not spared from such obstacles to learning.

This same abundance of paperwork and governmental procedures is present in teaching and education. For teachers, the teaching, learning, and students are first, but there are so many other things with which we contend on a daily basis that sometimes the learning gets lost. We are conditioned to become so concerned with discipline and whether or not there are too many referrals. Teachers are barraged with paperwork to document everything from how much paper the students use to the student dress code. Mandated curriculums and standardized testing, too, hamper what could be done in terms of true learning.

*Security office at EPA.*

## Contextual learning

The theoretical framework most closely related to a contextual learning experience would be that of the constructivist epistemology.[5, 11] Contextual learning allows learners to experience science, by direct participation in the research process. Through this process, I experienced the culture of science, using the language and discourse[8] of science, thereby learning science in the context of "researching" the subject matter.[4]

For the prospective or practicing science teacher, contextual learning within the constructivist framework:

- Involves a process of personal learning
- Is empowering

*The collaboration between a nearby research facility and the teacher's school can provide many rich learning and sharing opportunities.*

- Is a tool for critical reflection
- Allows the culture and language of science, not found in "textbook science," to be experienced,
- Encourages the teacher (i.e., the research mentor) to take on the roles of provocateur, facilitator, and co-learner, as opposed to dispenser of facts and information
- "Connects" learners to science
- Allows each stakeholder (the teacher and research scientist), through the interpretive process, to have a voice in decisions as opposed to one side or the other
- Allows the teacher to see research as analogous to learning rather than to truth-seeking[9]
- Encourages the teacher to see that frustrations, unsolved problems, and unanswered questions are part of the learning process, not failures
- Is a catalyst for teacher change with respect to channeling such beliefs and practices into his/her own classroom

The learner—in this case, the teacher—who is involved with the contextual experience, is allowed to construct his/her own meaning from the experience. The research process immerses the learner in the culture and language of science,[8] without forcing the students to learn useless information. The teacher as learner is able to reflect upon these experiences, compare them to traditional textbook learning experiences, and understand that this is a far richer step to learning. This is then channeled to his/her own classroom, where the constructivist example may be implemented.

*Beyond the "tourist" experience*

Based on my own personal experience, I feel that all science teachers should participate in a contextual learning experience at some point in their careers. The benefits are innumerable, not only for the students, but for the teacher's own professional and personal growth. There are many programs with this type of learning focus, such as NEWMAST (NASA's Educational Workshop for Mathematics and Science Teachers), NOAA's Marine Ecology workshop in Key Largo, and Monsanto's Teacher-in-Residence, to mention a few. These programs do not actually have the teachers "doing" research, however. The programs involve more touring and observing. I have been a participant in all three of these programs and believe they are excellent programs rich in content and ideas. The programs, however, keep teacher participants at a distance from the actual research and the process of science. One problem associated with having teachers participate in research is that many science teachers do not have the background in science content with respect to laboratory technique and research experience.

*Giving teachers opportunities like I had*

Throughout the country, there are many research experience programs for practicing teachers, referred to as the SWEPT (Scientific Work Experiences for Teachers) program through the Triangle Coalition. Also, there is an NSF-funded national program for practicing teachers to experience scientific research at the University of Florida[1] called TRUE for Teacher Research Update Experience program (On line: http://www.cpet.ufl.edu/TRUE/HOME.HTM). A preliminary literature search of these programs yields great promise for offering authentic research experience for teachers.[7]



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Most professionals endure a lengthy residence prior to becoming a full-fledged practitioner of their craft. Teachers generally only serve one semester of internship. Is this really a lengthy or diverse enough experience to become an effective teacher?

Teacher preparation programs should involve more extensive experiential learning. Universities can play a major role through more "creative course offerings." Many of the education courses offered in teacher education programs are repetitious and contain content that is mostly useless in the "real world." Teachers echo this lament, "We know the educational jargon. Put us in the classroom or in a laboratory setting where we need to be!"

*Dr. P. Schoor, and Lori at the EPA Lab.*

Teachers of other disciplines could benefit, as well. This could be adapted to a social studies teacher participating in work related to geography with a mapping service, studying social sciences with a sociologist or social worker, or history at a museum. A physical education teacher could be placed in health-related work, sports medicine, physical therapy, or occupational therapy. A language arts teacher could work in publishing, reporting, writing, or editing. This might involve working at a newspaper or editing at a magazine office. A mathematics teacher might assist a statistician, an accountant, a computer analyst, or an engineer. An art teacher could experience working in an architecture or drafting office, an art museum, or possibly with a local artist. The possibilities are endless.

*Terrie, Dr. P. Schoor, and Lori at the EPA Lab.*

*There's so much more involved in science than what they (other teachers) think. When you are immersed in science, you begin to realize that more*

According to the TIMSS (Third International Mathematics and Science Study),[10] unlike new U.S. teachers, new Japanese and German teachers undergo long-term structured apprenticeships. The TIMSS findings pinpoint specific areas where American education can improve. This includes better teacher preparation and increased opportunities for professional development for teachers.

From my own personal experience, I strongly adhere to the belief that in order to learn and appreciate science, teachers and students must also have some connection to science. Contextual learning fills this void. I learned more about chemistry during the 13 weeks I spent at the EPA than from all of the chemistry courses I have ever taken. Teachers are not the only ones to benefit and learn from such experiences. Any college student enrolled in a science course—that includes contextual learning experiences—could benefit from this type of experience with respect to content. Contextual

learning can help teachers to understand why and how this type of strategy can be integrated into their own curriculum and classroom. In turn, their students will learn from participating in contextual learning situations of their own.

## From laboratory to classroom

I feel that it would be prudent for colleges and universities to offer this type of learning experience as a research component of their teacher education programs to ensure that all prospective science teachers have the opportunity to participate and receive college credit. The benefits of this far exceed any classroom experience—particularly one that involves mere lectures, excessive readings, and long periods of sitting. Teachers should show some empathy when giving students "busy seat work." It is indeed boring. Immersing one's self—mentally and physically—is far more conducive to true learning.

Through my research experience and the resources afforded me by the EPA, I have produced a collection of lessons for use in the classroom, which are related to my experiences. These are unique in that most middle grades' science textbooks do not include sections on marine toxins. I have also been able to compile a resource list that includes individuals from the EPA who will be willing to serve as guest speakers, science fair judges, and student mentors. This is an additional benefit for my students. These resources can be further useful to students for science fair work or other research assignments. The collaboration between a nearby research facility and the teacher's school can provide many rich learning and sharing opportunities for both parties involved.

## Learning through active transport

The simple act of being in a real research laboratory is empowering. As I sat at my desk in the laboratory looking at the equipment, I felt that I was learning through active transport, to borrow a metaphor from chemistry. This feeling of empowerment is one you do not get by simply reading about the research of others. It has to be experienced! This has led me to focus my own dissertation research on contextual learning, as I am working with others on an NSF grant in teacher preparation in the state of Florida. Part of the grant will fund contextual learning experiences for prospective and practicing science teachers in my school district.

A form of contextual learning, through environmental service learning, has proven tremendously successful among my students, who are predominantly "at risk." Although, I have only recently begun to look at this approach in a critical and interpretive vein, I have long held the belief that students learn more when they are physically and mentally involved in a productive effort that has some purpose and meaning. Environmental service infused with contextual learning provides such an opportunity.

*A drawing of a scientist by a middle school student in Lori's classroom, prior to a unit in Science, Technology, and Society.*



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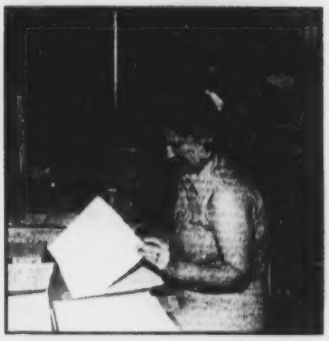

*Lori reflecting on her data and experiences.*

**Lori Livingston Hahn**

Years Teaching: 14

Present Positions:

Professional/family leave from middle school teaching to pursue Ph.D. and stay home with son

Graduate student in science education at Florida State University

*"It was interesting to know the procedure even though our hypothesis was not correct."*

*"Working concurrently with a research scientist offers the teacher a first-hand glimpse of the culture and language of science."*

*"The collaboration between a nearby research facility and the teacher's school can provide many rich learning and sharing opportunities for both parties involved."*

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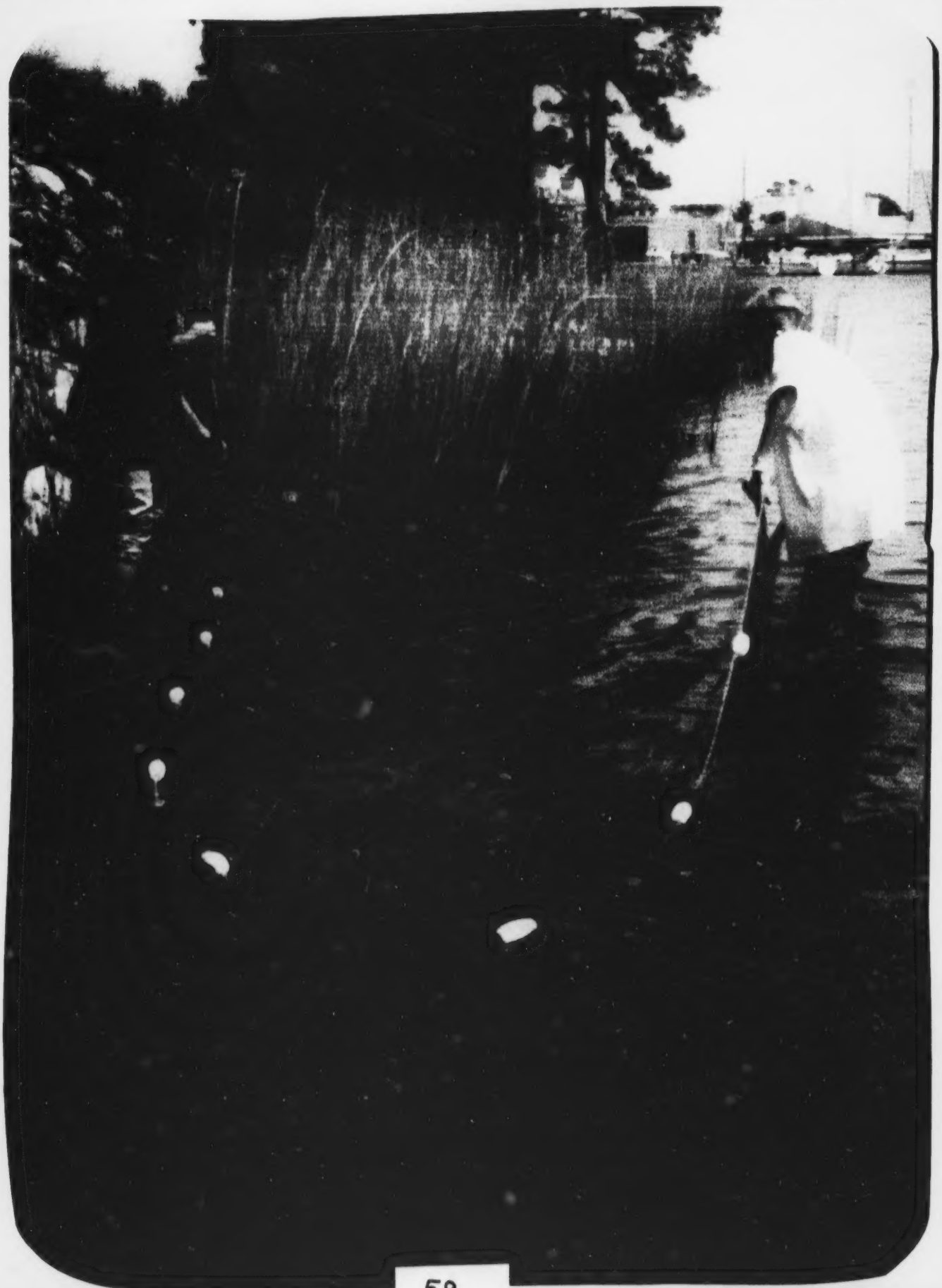


## Prologue

*When your hero is Jacques Cousteau as a kid, it is a dream come true to spend a summer studying the movement of gray snapper fish in the St. Andrew's Bay. This is just what Joe Brock did in his study,* "Ghost Shrimp and Fish Bring Real-World Experience to a Science Classroom." *To assist the scientists with his research experience, Mr. Brock had to read in order to develop the background knowledge necessary for the field work. Besides learning that scientists have to read a lot, he learned that sometimes it is necessary to improvise when the tools and equipment you have do not get the job done. This is exactly what Mr. Brock did, and it was his alteration of an anchor that allowed the study to proceed. He also learned that sometimes it was necessary to pull "all-nighters" in order to gather his data. His research experience changed his perspective on the nature of science. Mr. Brock has brought his practical application for problem-solving and learning concepts back into his classroom. His students have been involved in a three-year project, studying the dominant fish species in a local bayou. Each month as they venture out to conduct research for the National Oceanic and Atmospheric Administration (NOAA), Mr. Brock is living his boyhood dream.*

# Ghost Shrimp and Fish Bring Real-World Experience to a Science Classroom

*Joseph Brock*

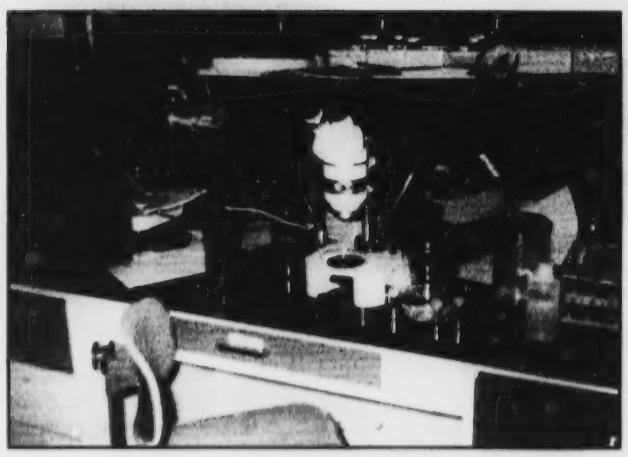
## Towards fulfilling a lifelong dream

The summer of 1996 had my imagination racing with the fulfillment of a life's dream come true. I have always wanted to work in marine sciences ever since I was a child. Images of past episodes of *The Undersea World of Jacques Cousteau* and *National Geographic* flooded my memory when Dr. Penny J. Gilmer suggested I pursue an active research project in a field of science that interested me. With this lifelong dream in my mind, I contacted the National Oceanographic and Atmospheric Administration (NOAA) Marine Laboratory situated just one mile from my home for a possible project.

*This was the best summer of my life.*

My purpose for participating in a scientific project was basically two-fold. First, the experience was designed to immerse me as a science educator into the culture of science and the language of practical scientific research. As a middle school teacher of science, it is paramount to understand how science and scientists work in the field, so that I can relate that understanding to my students. It is also important to understand the implications of scientific work in the real world and the influences that science has on our lives. This experience influenced my perspective both on the nature of science and on the teaching and learning of science for my middle school students. The second purpose of the project was to fulfill the needed graduate student hours in science content to satisfy an important component of the doctoral program in science education at Florida State University.

## Growing Pains



*Inside the lab where Joe did his research.*

I first experienced science research practices in a master's degree program called Science FEAT (Science for Early Adolescence Teachers).[10] This was an intense three-year program that encompassed six intensive weeks of study at Florida State University each summer with work in our classrooms during the two school years. The program was instituted to offer science teachers experiences that would enhance the teaching and learning of science in the classroom resulting in an advanced degree in science education.

My first real experience in actual science research was in the summer of 1994 when I was assigned to the Florida Freshwater Fish and Game Commission to help out with a flathead catfish project. There had been complaints lodged by local fishermen that the pan fish and bass population seemed low, and the flathead catfish were suspected of eating the fish. We were charged with carrying out a collection program to determine if the catfish had, indeed, decimated the fish population and if there could be some correlations drawn between the growth rings in the pectoral spine and the weight and length of the fish. It was hoped the freshwater fishery scientists could then project the rate of growth of the flathead catfish and approximate how much fish it may consume if, indeed, it was the culprit. Our results concluded the flathead were eating crayfish and not fin fish at that time of the year.

*Panfish is a term that includes a wide variety of species that fall in the sunfish family such as bluegill, sunperch, shell crackers, and pumpkin seed fish.*

*Joe snorkeling in the bay.*

It was this program that prepared and inspired me to take on a more rigorous project at the NOAA marine laboratory in 1996. The flathead fish project allowed me to learn various techniques of sample collecting, slide preparation, organizing data, and analyzing results. My principle job was to prepare samples and view the prepared samples under a microscope and count growth rings of the pectoral spine. This meant the spine that grows from the fin at the breast of the fish had to be disarticulated (i.e., removed) from the fish and sliced into a very thin slice, so light could pass through it to count the growth rings. We made correlations of the number of growth rings present to length, weight, sex, and stomach contents. Consequently, the experience of dissecting 175 fish on a hot summer day while working outdoors surrounded by flies and biting mosquitoes smashed my previous concepts of what scientists do and how they go about doing it.

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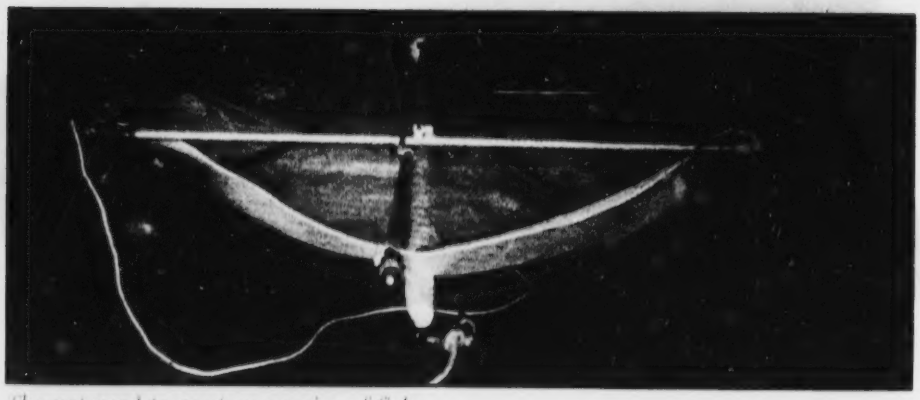
*for sewing net together.*



*The net used to capture species of fish.*

My previous thoughts pictured people working under sterile conditions with the technicians charged with the messy work. I also thought these scientists could get anything they needed for their work by simply asking for it. I was surprised to find much of the equipment was garnished from hardware stores, frequently paid for out of the scientist's pocket. There were flashes of ingenuity when we had to substitute a piece of needed equipment by concocting a way of building it out of available local materials. I kept a journal of my experiences and how those experiences could be translated into teaching science to middle school students.

## Greater experiences translate into greater understandings

The NOAA project had a similar objective to the Freshwater Fish and Game Commission project: to try to understand how the fish population was faring against the odds of pollution and environmental degradation. The focus of the NOAA project was to determine and try to understand the mechanisms of transport for the juvenile gray snapper that transit the pass in the bay in Panama City, Florida. These snapper, which only measure two millimeters, settle out on the bay's sea grass beds and remain there until the fall when they have grown large enough to move back to sea.[1-3] In the span of three months, these fish grow from two millimeters to an average of 10 centimeters.

The idea of the project was to determine if these juveniles pulse through the pass or if they trickle in throughout the summer. We also wanted to know if there were physical parameters controlling the movement of the fish into the bays.[3] For example, it is known many juvenile fish will take advantage of the dark of a new moon[4,5,9] and high tides to pass through channels or passes to reach the rich feeding grounds of sea grass beds, where they'll find relative safety without detection by predators. Conditions like a new moon and a rising tide ensure a higher survival rate.[6] However, not all juvenile species use these conditions for passage.[7] Some may use strong onshore currents and winds or salinity differences. Others may simply trickle in at all times under any condition and rely on vast numbers to ensure survivability of the species.

*We went to a hardware store and invented our own types of ideas literally. That was a skill I learned: to be adaptive, to invent, and to learn whatever it is you need to get the job done.*

Dr. Gary Fitzhugh was my mentor at the laboratory, although I was assigned to Dr. Bob Alman for the field work. All of the scientists at the laboratory made me feel very comfortable and were always eager to help answer my questions.



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*Parts used to invent anchor to hold channel net to the bottom.*

*Joe with his own invented anchor.*

My first assignments were to read as much research as I could get my hands on about juvenile fish transport and what other scientists were doing in similar fields of study.[1-9] I spent just as many hours reading as I did in the field. I realized how important the reading was during the design phase of the project. Through daily informal conferences, we would discuss the ramifications of the work of other scientists to help guide us on how our project would be designed and implemented. After three days of research and discussion, both Gary and Bob instructed me to design and build a frame for a channel net with an anchoring system that would be deployed at night in the channel. They exhibited confidence in my ability to complete the task in five days and gave me total control over the construction.

I constructed the net so it had an opening of 2.5 by 3 meters and a bag length of 9 meters. The bag length is the actual length of the net from the opening at the mouth of the net to the end of the net that supports the cod device which traps the juvenile fish. The net was to be deployed from a boat in six meters of water and had to have a flashing light system to ward off collision with commercial and recreational boat traffic. The net required three people to deploy and retrieve it. At the end of the net, a cod collector trapped the specimens throughout the night. The net was retrieved at sunrise each morning, and specimens were preserved in 95 percent ethanol. All juvenile fish were separated by hand using dissecting microscopes and were identified by genus.[7,8] All snappers were further identified by species. Each day began with the retrieval of the net, preserving the species, cleaning the net, and identifying the collection by genus and species. By sundown of each night, the net was deployed again, and the cycle would commence again.

Our first night of deployment had all of us wondering if the system would work and if it could avoid collision with local boat traffic. That first night found all of us in an 18-foot boat anchored nearby all night just to convince ourselves that the net would be safe, the flashing strobe light system worked, and the net would swing as the tide shifted. I realized scientists will work around the clock out of dedication just to do the work, without a thought to economic compensation. Overtime pay did not apply to this group of scientists!

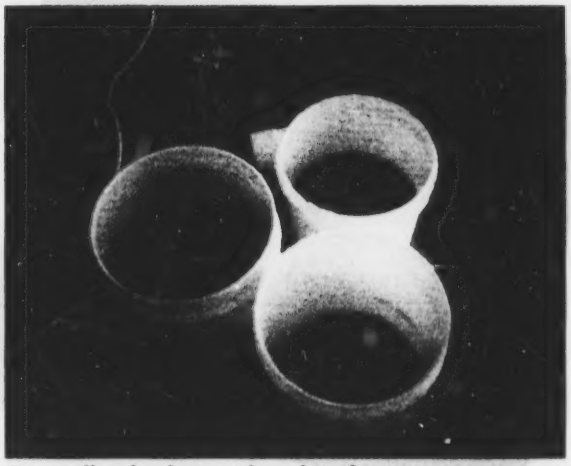
Another interesting paradigm that was built from this experience is the fact that much of the work borders on being tedious and very repetitious. It would take three days sometimes to go through the buckets of specimens to tease out the fish. Then there were the endless hours of microscope work to identify the catch. I stayed long after the laboratory closed, just to try to keep the material from becoming unmanageable. Each genus and species were placed in separate vials and labeled with the date, time, and physical conditions of capture.

The results of the study indicated that the pulse of gray snapper into the St. Andrews Bay system was on nights of new moons and only in a two-month period between June and August. Gary felt strongly about my making an oral presentation for the Florida Federation of Freshwater and Saltwater Fisheries conference, held each February in Brooksville, Florida. Here, I was given an opportunity to mingle with other scientists and present my findings in a formal setting. As a consequence of the experience, I now believe each teacher who has an opportunity to become involved with field

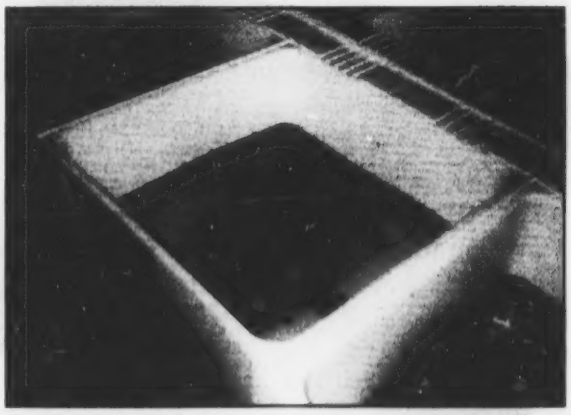
*I had to make a presentation in Brooksville on our results of the project. I think anyone working with a scientist should do this. It's like being involved in their culture.*

work should at least attend, if not present, at a scientific forum. This is where the culture of science becomes expressive, and results become springboards for further questions.

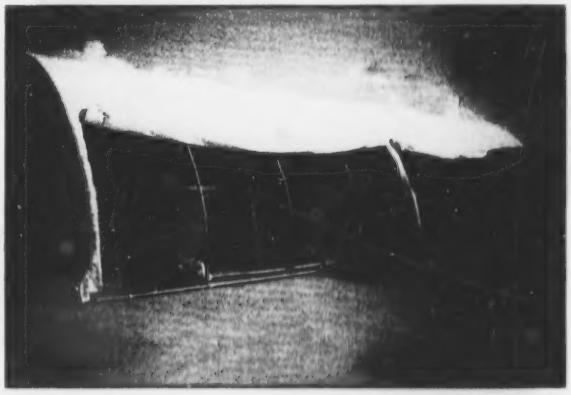
The information gathered from the gray snapper project can be used to determine the health of the population for the gray snapper fisheries by comparing successive years of collections of juvenile fish caught in the net and calculating the number of fish moving per cubic meter of sea water. This study did not have any conclusive evidence since it was the inaugural procedure of the study. Subsequent years of comparisons will be useful against this baseline data. The data that Joe's students collect are available on the Internet and shared with local scientists through Bay Watch.



*Five gallon buckets with cod in them.*



*Turtles captured by the net—they were eventually released.*



*Shark tanks.*

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## Teaching Real World Science

*[This experience] has given me a greater appreciation for what science is and the nature and culture of science.*

The lessons learned from this experience did not go unharvested. As a result of experiencing how scientists work in the field, my middle school science classes of the last two years have evolved. I emphasize more the practical application of learned concepts and problem-solving. For example, if I am introducing a lesson on the concept of buoyancy, I will give my students equal-sized pieces of aluminum foil and challenge them to build a boat that will hold the greatest number of marbles. If I am teaching how scientists classify living organisms, my students are given 15 different kinds of beans and challenged to create a classification system with explanations of why they designed the categories the way they did. Then, to really see if their systems work, each student is given a peanut and challenged to place the nut within their system using their categories.



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*Lake where students conducted their research.*

*Student seining in bay.*

The NOAA research experience taught me that science has a culture all its own. If we hope to have a future population of citizens who understand the implications of future research, they, too, must be acquainted and at some point fluent in this science culture. This means that we, as science teachers, must teach from the standpoint of developing understanding in the learning of science for our students. Content is not enough! Frames of reference should be developed and then challenged for understanding to be meaningful.

As for my middle school students in science, they are currently researching the dominant populations of fish that inhabit a local bayou each month. We are interested in discovering what kind of physical parameters predetermine the shifts in the populations of fish in the bayou. Because of the need for special equipment, my students have participated in writing a grant to receive funding for the project. They have learned how to use very sophisticated titration equipment to determine salinity, oxygen and carbon dioxide concentrations, levels of nitrates, pH, and water hardness.

*Joe's students using a seine net.*

The project is in its second year and slated to continue for three more years with monthly visits to the bayou where students seine out a predetermined section, collect chemical data, identify, and count species of captured fish. As a result of this project, I think my students are benefiting from my experiences of active scientific field work by my giving them a window of opportunity to become immersed in a meaningful field study, a field study that encompasses many of the characteristics of real-world science.

*Students measure out a meter plot and count species.*

## Changes in my classroom

*Students examine their findings in the bay.*

My changes as a classroom teacher and learner of science have been profound. My working paradigm of what science is and how we interact with it have principally changed to encompass science as an action to learning. Our learners must be involved mentally in the science, and as educators we have to recognize not just what is important to teach but how to best go about it as a scientist. The teaching and learning of science should be an adventure with more questions asked than answered. As individuals, we have to examine our purposes for teaching science and ask ourselves if we are involving our learners in the art or merely reteaching the products of science.

I would argue that science content is, indeed, important but not at the expense of process. The flathead catfish and gray snapper experiences have reinforced in me the importance of experience and that content without context becomes meaningless. As teachers, we to have to be adaptive and ingenious. It is all too easy to blame the lack of funds or lack of support for a meaningful science program that offers experiences. I have come away with the knowledge that nothing is impossible in the classroom, and it took two science

*Students sort, classify, and count the number of species collected.*

*Students sort, classify, and count the number of species collected.*

*Last year the marine lab called me and said the Navy had a question of how cable lines are getting snipped. Our thought is that the ghost shrimp might be doing it. We want to know why.*

field experiences and the patience of a few scientists who mentored me to formulate this realization.

Another advantage of my summer's research was contacts to real scientists as resources and mentors in the classroom. These scientists have presented my classroom science students with a problem they are interested in answering. Apparently, a construction company is having serious problems with a fiber optic cable that is constantly being severed in hundreds of places and remains a mystery to the company. Laboratory scientists want my class to develop, design, and implement actual field experiments to determine if ghost shrimp living on the bottom may be responsible for destruction. This is exciting because now my students are researching a problem that currently has no answer, and they could be instrumental in constructing valuable information in real-world applications of science.

**Joseph Brock**

Years Teaching: 18

Present Positions:

- 7th-grade middle school science teacher at Rosenwald Middle School, Panama City
- Teacher of elementary methods course at Florida State University, Panama City campus
- Graduate student in science education at Florida State University

*"It was a heck of an experience. It's like being involved in their culture. It was the richest experience of my life."*

*"I think the [best] thing [about this experience] was the adventure of it all. I'd do it again in a heartbeat."*

*"One of the skills I picked up was that science itself doesn't have time limits."*



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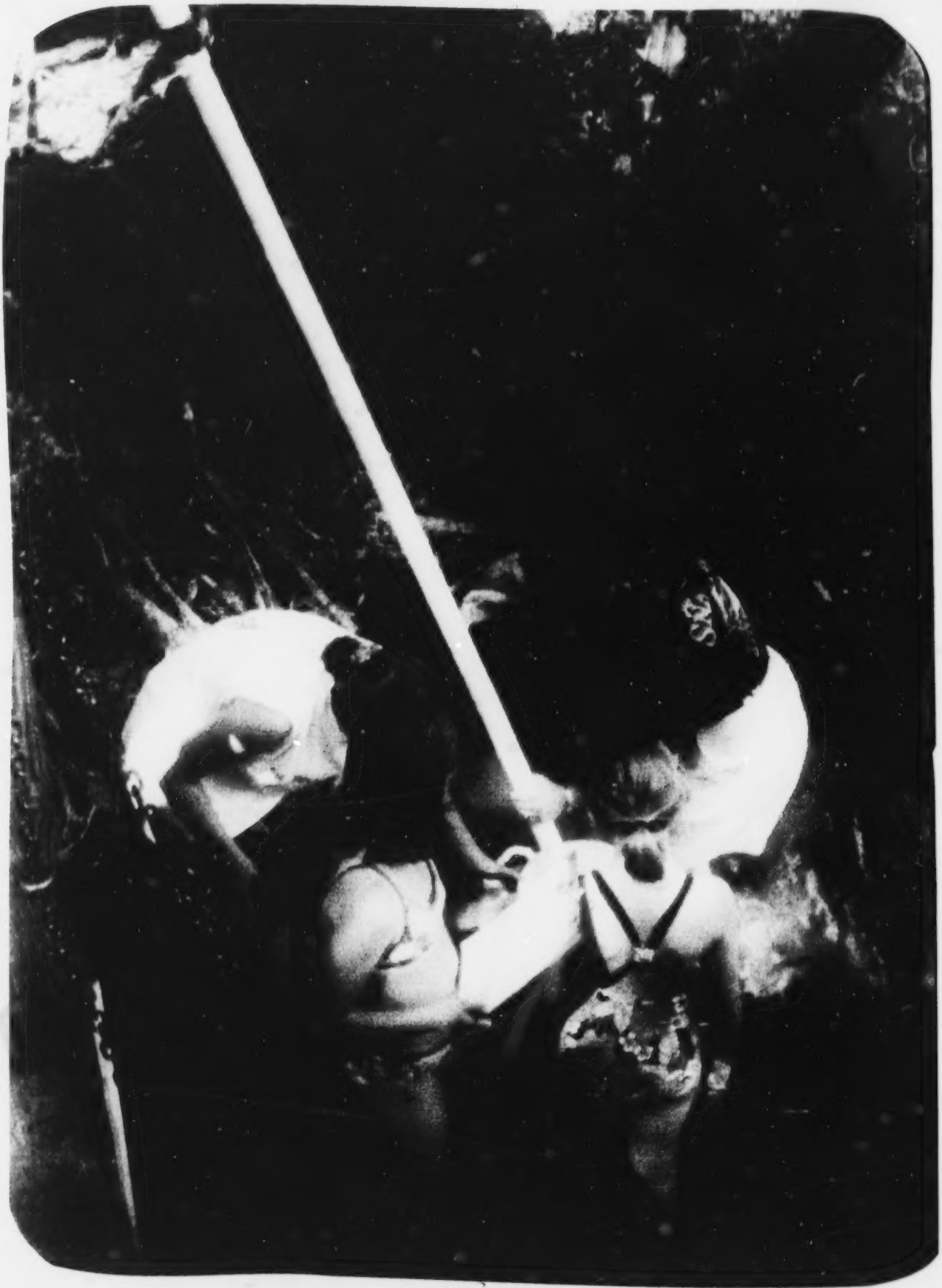

## Prologue

*In a summer workshop called TRUE (Teachers Research Update Experience), which paired middle and high school teachers with a scientist, Terrie Kielborn tells of her experience working with algae in* "Blossoming of Science Involvement through Algae Research." *Her experience took place predominantly at the aquatics laboratory where she learned to use sophisticated laboratory equipment and protocols to learn about algae. Working alongside other scientists allowed her to think and talk like a scientist herself. The field experiences on the St. John's River where she collected water samples made such an impact on her that she knew she would have to create something similar for her students. She has written proposals and received several grants that will allow her middle school students to get "wet and muddy" as they conduct water quality tests on a local lake.*

# Blossoming of Science Involvement through Algae Research

*Terrie L. Kielborn*

## My "TRUE" experience

The summer of 1997 brought more than 100°F temperatures to this sixth-grade science teacher from Ocala, Florida. Through circumstances of fate, I became a participant in the TRUE (Teachers Research Update Experience) Program, an NSF-funded program pairing practicing teachers with researchers. I was placed with Dr. Edward Phlips at the Fisheries and Aquatic Sciences Laboratory at the University of Florida. This experience also assisted in fulfilling part of my doctoral requirement of independent scientific research under the guidance of Dr. Penny J. Gilmer at the Florida State University.

For five weeks, I was transformed from teacher to laboratory researcher with the guidance of my mentor, Jennifer Kalberer. Learning various laboratory techniques and processes included demonstrations, explanations, and a gradual taking of responsibilities, which gave me, a practicing teacher, "first-hand" experience in science. First-hand experiences are how human beings learn best.[11] There will be a continuation of similar experiences through communication and collaboration, which will include laboratory visits, field trips, and e-mail. Grants, from Dow Chemical Company, the Florida Science Institute, and Marion County Public Schools Foundation, which I was awarded for the 1998-99 school year will allow my students to conduct their own science research study of a local lake.



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## My induction in a laboratory

*Terrie sits by the electron fluorescence compound microscope, which uses a laser light for viewing the syn algae she studied.*

TRUE is a summer program which pairs middle school and high school teachers with scientists (On line: http://www.cpet.ufl.edu/TRUE/HOME.HTM). It is directed by Dr. Mary Jo Koroly at the Center for Precollegiate Education and Training at the University of Florida. The experience includes learning about a variety of scientific topics through listening to lectures, participating in field trips, creating individual Web pages, sharing ideas for best practices, undertaking a scientific research experience, developing a Teacher Action Plan, preparing a written summary of the laboratory research experience, making a formal presentation of the laboratory research experience, and sharing in fellowship with other teachers and scientists.

Dr. Edward Phlips specializes in Phycology and Aquatic Microbiology. Recently he has been researching plankton species in the Florida Bay and the St. John's River. He is particularly interested in finding out what effect these two phytoplankton species have on the ecosystem and other related species within that ecosystem.

His colleagues, Susan Badylak and Mary Cichra, assisted Dr. Phlips in conducting and analyzing data for his research. Two laboratory mentors, Jennifer Kalberer and Tammy Grosskopf, taught me a multitude of laboratory procedures and techniques.

In the previous summer of 1996, I had enjoyed another research experience in which I was constantly out in the field and periodically met with the supervising biologist. This research experience was entirely different, in that it provided daily contact with the supervising scientist and involved working inside a laboratory alongside mentors, conducting experiments with samples and two days out in the field collecting samples.

In 1997 I kept two journals, one with daily entries during the five-week period to record my reflections, questions, and general procedures, and in the other I logged laboratory techniques and procedures, such as filtering for chlorophyll or inoculating algal cultures.

*Terrie (left) discusses her project with Dr. Phlips.*

Dr. Phlips wanted me to conduct my own mini-research project. This experience was empowering because I was forced to use and apply all that I had learned so far in the laboratory. I now see how this experience has transformed and empowered me as a person, teacher, and graduate student. Empowering people results in their taking greater enjoyment in their work.[1] Empowerment unleashes energy, stimulates creativity, and encourages risk-taking.[4] As a result, I have created a series of activities to implement with my students to simulate my own experience as a science researcher.

*It's funny. When you learn something for the first time, it feels like an impossible task that you will remember everything.*



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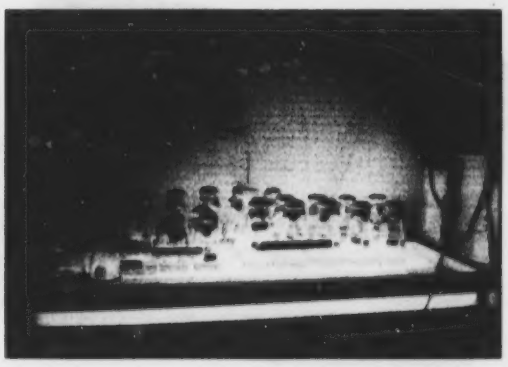
## Creating my own understanding

As I began my laboratory research experience with the TRUE Program, I was very anxious and nervous, much like one of my students on the first day of school. As my first day progressed, I became so overwhelmed and saturated, from the explicit multitude of procedures and terms, I had to take some aspirin to relieve my spinning head. This was an important reflection as I could actually identify with some of what my students experience.

As I learned the steps and procedures for conducting laboratory work, I had to make sense of what I was learning to create understanding. To do this, I combined my prior experiences with my new learning experiences. Experiences give us insight and knowledge about teaching.[6] Things that were difficult for me to understand were due to my lack of prior experiences regarding that concept. As these new experiences and understandings became part of my schemata, they increased my levels of confidence and scientific knowledge. I was experiencing the constructivist environment, which I try to provide for my students. The constructivist approach allows the learner to construct meaning, using prior knowledge for building new knowledge. This combination of new and prior knowledge develops a high level of understanding or schemata.



*Lab experiments on two different types of algae—*Syn and Skeletonena*—shown under controlled lighting and temperature conditions inside culture labs.*

The cogon[illegible]ss research I had experienced the previous summer gave me a great insight to working in the field and calculating data, but it was much different from working in a laboratory setting alongside the scientist and laboratory personnel. I can still recall the first day when Jennifer showed and explained to me the procedure for obtaining samples for a fluorometric reading. A fluorometer is a device that detects the amount of biomass or chlorophyll in a particular sample. Whenever I had a question about a technique or piece of equipment we were using, Jennifer would simply share her knowledge, which gave me more confidence and a comfortable level to learn. I wrote about her in my journal:

> *Jennifer is a good teacher and is very patient with me. She does not make me feel like I'm a burden, and I appreciate that immensely.*

I know that she never considered herself a teacher, but she had all the important gifts—teaching with patience, giving me encouragement, demonstrating, then facilitating, and supporting me through my successes and mistakes.

*Terrie is pipetting a salinity solution into each flask of medium (a special vitamin mixture used especially for studying algae).*

This research experience gave me a wealth of knowledge, helped me develop new skills, and caused me to reflect on what science is and what scientists do. Teachers can gain current and accurate information about scientific discoveries while they are made compared to the lag time evident in publications or textbooks.[12] Since my own background was weak in microbiology, I read many journal articles and papers, most of which Dr. Phlips provided

for me. In the laboratory, I learned about and worked with two types of phytoplankton in Florida—*Skeletonema costatum* and *Synechococcus*. Working with others in the laboratory setting, I was able to develop a multitude of skills necessary for conducting research in aquatic microbiology. I learned such things as making slides from samples, filtering for chlorophyll, filtering seawater, making media, using high-technology equipment such as the fluorometer, inoculating cultures into media, using light microscopes for viewing container samples, and using the compound fluorescent microscope with lasers to conduct cell counts.

One of the laboratory personnel, Mary Cichra, the senior biologist, used to teach fifth and sixth grade. She was extremely helpful in suggesting ways to conduct a simulated research study on aquatic microbiology in the classroom. I especially valued her expertise because she had the advantage of having the perspective of both a scientist and a teacher. I was amazed how easily she could adapt an intense science procedure into a very cost-effective method that I could take back into my sixth-grade classroom to conduct with my students.

One day, there happened to be a group of high school seniors visiting Dr. Phlips' laboratory, and they were considering possible careers in the Fisheries and Aquatic Sciences. I mingled with two of the groups—one on fisheries and another on aquatic entomology. This experience allowed me to make yet another transformation, this time into the role of student. In a very short time, I became an active learner and began to reflect on how I could relate these experiences to the classroom.

The days I spent in the field on the St. John's River were the highlight of my summer research experience. I was able to collect our samples along with the scientists from the St. John's River Water Management District from the City of Jacksonville. Not only did I learn and experience the procedures for collecting water samples, but I learned some of the techniques for conducting various water quality tests such as light intensity, pH, and dissolved oxygen.

*Terrie marks date and time collected for each sample on the St. John's River. (She is taking a break from using the water sample pole.)*

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*The TRUE experience left me in awe of science as a discipline and in awe of myself—what I had accomplished in those seven weeks.*

The basic mechanism for learning in humans is experience.[4] Dewey, Tyler, and Piaget all advocate experiential learning.[8] After those two days, I truly felt like I had experienced what it was like to be a scientist and gained a perspective of science research. I had experienced contextual learning. Contextual learning is the process of experiencing the culture of science, using the language of science, and learning science in the context of researching the subject matter.[3] A theory by Lortie[7] says that we gain a perspective during an apprenticeship of observation. Our perspective of what a teacher is stems from the experiences we had as a student in our K-12 education. But, this is only a learner's perspective. Once you become a teacher, then you begin to acquire the teacher perspective. What this experience has done for me, especially on the day I spent on the St. John's River, was to break this cycle. Originally, I had the idea from my experience as a student that knowledge was a transmission of facts. We have a mental model of teaching, and as teachers we teach as we were taught as a student. This experience as a scientist on the St. John's River has given me a different model—the perspective that knowledge is a process of coming to know through experimentation and discovery.

My TRUE laboratory research experience can now be an infectious prelude for a year of scientific inquiry and discovery for my sixth-grade students. Students can now learn laboratory processes and techniques from me and conduct their own scientific research using local bodies of water. At the time of this writing, I have immersed myself in several extensions of my TRUE laboratory experience and have touched only the surface of its impact. I have constructed a new view of science from this science laboratory experience, and it has already changed the way I teach. Teachers can only teach science as they have experienced and understoond science.[2]

## Coming to understand algae

*An electron microscope view of the Skeletonema algae Terrie studied with Dr. Phlips.*

## About algae

The focus of the research included two phytoplankton: *Synechococcus* (Syn), a cyanobacterium, and *Skeletonema costatum* (Skeletonema), a diatom. Separate cultures of each plankton were injected into a vitamin-rich mixture

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called *media*. Different salinity concentrations were added to the media, and then the phytoplankton were allowed to grow in the culture. Cell counts using the microscope were compared to fluorometric readings. The Turner Fluorometer we used was very sensitive in detecting the amount of chlorophyll in a sample.

*Since I was the only one taking these readings (secchi disk), the data depended on my performance. What a responsibility! But everyone had confidence in me. No one questioned what I did. It was a good feeling.*

Syn is a blue-green algae capable of adapting to a wide range of salinity levels. Syn has been of particular interest to scientists and water managers because of its threat to coral reefs, including sponges, lobsters, keyfish and shellfish populations, and seagrass communities.[10] In one of our discussions, Dr. Phlips said that where there were once 100 sponges per acre in areas of the Florida Bay, now there are less than 10. Human interactions, such as the creation of the Flagler Railroad and Alligator Alley, have limited the fresh water flow that Florida Bay once received. This lack of fresh water flow has led to the increase in salinity now found there. High-salinity gradients make very favorable conditions for Syn to grow. These Syn blooms are close to the surface and block out most of the light for the rest of the organisms in the water column.

Skeletonema is a one-celled plant (or diatom) joined by chains of varying length. It is the most common diatom in the Gulf of Mexico.[5] There is a scientific discussion on whether or not *Skeletonema costatum* is being affected by variances in salinity, or whether there are different species at each salinity level. There are times of the year when the St. John's River has high-salinity levels 60 miles south of its connection with the Atlantic Ocean.

## Why study algae?

Plankton productivity is directly related to fluctuations in fish populations.[9] By studying phytoplankton, we can study other species within the food web. This will give us a better understanding of water management strategies and environmental effects on oceans and river ecosystems.

## My mini-research study on algae

Medium, a vitamin solution which is conducive to a fresh water environment, was made using the procedures described in Standard Methods.[13] Artificial salt-water mix plus nitrate (A + N) media was used for the injection of the Syn, and A + N plus silicon media was used for the injection of the Skeletonema. Each media type was autoclaved at 121°C. Autoclaving sterilizes the media with heat and extremely high pressure. Salinity gradients of 5 parts per thousand (ppt) through 45 ppt and 55 ppt were used for both experiments of Syn and Skeletonema. Salt content of seawater together with the presence of chelating agents and organic substrates are the most likely factors determining the growth and survival of terrestrial bacteria in the sea.[9] Brackish river water has a salinity factor of 30 ppt, while open ocean water has a salinity factor of 35 ppt.

*I've got the algae blues, That's why I'm singing this song. But in Dr. Phlip's lab, You know I can't go wrong.* (verse from "The Algae Blues." T. Kielborn)

The set of flasks containing the culture and media combination were set in a tank with distilled water under controlled temperature and lighting conditions in the culture laboratory. Every one-to-two days, I did readings to estimate the number of cells from the amount of chlorophyll present. Growth was also monitored using direct cell counts with measurements using a grid system at 400X magnification.

Light microscopy was used at 400X for Skeletonema cell strands and measurements. The compound fluorescent microscope was used to count Syn, using the *Standard Methods*.[13] Cell size was considered small if the diameter


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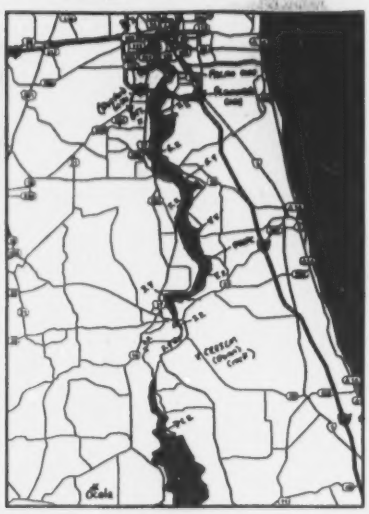
was less than 3 microns (or micrometers, m), large if greater than 3 microns but less than 5 microns, and extra large if greater than 5 microns. The smaller salinity gradients produced the small-size cells and fewer number of cells. The span from 10 ppt to 45 ppt produced large-size cells and a larger cell count. The 55 ppt produced a large-size cell but a smaller cell count. Size seems to concern the scientists, but from my own experience, I'm not sure why. This leaves a question of inquiry and investigation for me.

I was able to go out into the field, spending a day on the St. John's River beginning at Palatka to Lake George, then from Palatka to Jacksonville, and returning to Palatka. Samples were collected at 17 different stations in compliance with the St. John's River Water Management District (SJRWMD) field expedition team. At some of the station sites, we collected samples for Dr. Phlip's lab, some only for SJRWMD, and then some for both. We used a three-meter pole with a stopper at one end to collect samples so that a sample of the entire water column could be retrieved. Most plankton vary their position in the water column. On the Jacksonville run, samples were taken at the bottom and mid-range levels using a niskin bottle. We used a pole to collect the top sample. Samples were put into a large container and pre-rinsed with that station's water. At this point, containers were filled to be used for filtering, to study bacteria (these had to be stored on ice), and some were added to lugols, which is a preservative. All containers were labeled with the date, military time, and station site. We took the collected samples back to Dr. Phlip's lab where we studied the samples using light and compound florescent microscopy, to detect various Skeletonema species and bacteria.

*We did a lot of work, and it wore me out between the sun, being on the water, and pulling all of those samples, but I'll remember it forever.*



*Map of St. John's River indicating locations where Terrie collected water samples with St. John's River Water Management District.*

*Terrie prepares to lower the secchi disc to get a light intensity reading on the St. John's River.*

*The three women scientists who Terrie assisted on her field experiences on the St. John's from Jacksonville to the Atlantic.*



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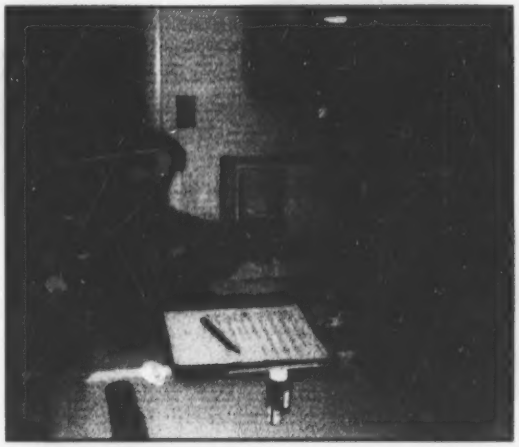
Once we collect the data, they are entered into a computer program in the laboratory; the conversion factors[13] are calculated; and graphs are plotted, followed by analysis. The data we collected from the fluorometer readings on both the Syn and the Skeletonema showed a wider range of tolerance for the Syn. By calculating the actual number of cells per mL, we calculated the number of cells at a particular station site in Florida Bay or the St. John's River, giving us an approximate amount of algae species in the water. By comparing the amounts we have now with that from the last two years, we can estimate the density of algae and use this to estimate the impact on other species within the same ecosystem.

## *What I found out about algae.*

The Syn grew at all salinity levels, more significantly at 10 ppt and above. The Skeletonema grew at all levels except 5 ppt and 55 ppt, but after the seventh day, it stopped growing. Dr. Phlips suggested that the Skeletonema used up all of the available nutrients in the media. At the time of this writing, we began a side experiment using an f2 media from Bigelow, a culture supply company. The medium utilized filtered seawater, vitamins, and trace metals as additional supplements. Also, light microscopy viewing revealed distinct differences in size and shape of the *Skeletonema* cells, and the spacing between the cells. The biologist confirmed some of the samples we had grown in the culture laboratory to those identified with "live" samples from the St. John's River.



*Terrie extracts various chemicals, then weighs each to use in making medium.*

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## TRUE repercussions

Through the TRUE Program, I have outlined a set of lesson plans, laboratories, and activities related to my experience. These will be exclusive for compiling data on several of the lakes and rivers within our community. These data will be shared with other scientists and students from around the world through the Florida Through a Global Lens project, The Florida Science Institute Water Quality Monitoring Web site, and the Florida LAKEWATCH Program. Personnel at the Department of Fisheries and Aquatic Sciences, SJRWMD, The Florida Science Institute, and Brevard Laboratories are now available as resources for students, as guides for field trip sessions, as mentors for students, and as e-mail partners.

This collaboration will provide learning experiences and opportunities beyond what I could have offered before TRUE. Students will also learn and develop laboratory skills, procedures, and techniques such as making slides of samples, preserving samples, recording data, analyzing and comparing data, using current research studies, and using light microscopy. They have just started to collect their own samples from a nearby lake to identify plankton and conduct a variety of water-quality tests. These data should

influence the other species within the ecosystem such as fish or invertebrates.

I have received grants from the TRUE Program, the Dow Chemical Company, Marion County Public School Foundation, Florida Science Institute, and donations and contributions from local businesses. These grants have allowed me to acquire the kits, materials, and equipment needed to conduct an indepth and interdisciplinary study of a local lake. Although students will explore environmental concerns, recreation, and water management issues, they will also have the opportunity to learn and apply the skills necessary for authoring and conducting scientific research. I have used my contact with the U.S. Geological Department of Water Analysis in Ocala, Florida, for obtaining distilled water.

*I love being a scientist! I think I'll make a banner that says this and post it on one of my classroom walls.*

Students learn best when they are involved in what they are learning and have ownership in the learning process. It helps students learn if what they are learning has meaning for them. I am no longer satisfied with the "cookbook-style" laboratories I had implemented in the past, simply because they are "hands-on" and "cover" scientific concepts. I want my students to venture out into the unknown and explore science much like the explorers we read about in our history books. I am planning for my students to make their own choices, implement strategies, and intertwine their imaginations using scientific processes. My present classroom is one in which my students are starting to make the same transition I did—from student to scientist.

*Sabrina gathers a water sample.*

*Nancy (left) and Sabrina use Hach dissolved oxygen testing kits to test water quality of a nearby lake in their community.*

*Kim (far left), Katie (front left, one of Terrie's daughters), Sarah (right front, another of Terrie's daughters) and Terrie (holding sample pole) get water samples at the Silver River for Kim's science fair project.*

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**Terrie L. Kielborn**

Years Teaching: 20

Present Positions:

- 6th-grade middle school science teacher at Belleview Middle School, Belleview, FL
- Adjunct professor for National Louis University in Instruction and Curriculum
- Part-time instructor for science and mathematics methods courses for Florida Southern College
- Graduate student in science education at Florida State University
- Co-editor of this monograph

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*"This experience was empowering because I was forced to use and apply all that I had learned at the laboratory. I now see how this experience has transformed and empowered me as a person, as a teacher, and as a graduate student."*

*A version of this paper was presented at the Southeastern Association for the Education of Teachers in Science, the 1997 Annual Conference in Wakulla Springs, Florida, and at the 1999 annual meeting of the Association for the Education of Teachers in Science in Austin, Texas.*

## Transition

*by Terrie Kielborn*

Talking and importing facts
from the laws and ideas
of great dead men.

*What's up? Sitting*
*in here. But*
*Mrs. K. is cool. Later.*

Procedures, protocols.
So much that I wrote my thoughts
down so that I could remember.

**Lower the disk until it disappears.**
**Pull up and measure.**
**Rinse first. Put those on ice.**
**Mark the place, date and time.**

Beyond the sameness of my room and faces
I stood with rebirth
A gift waiting to be unwrapped.

*Don't forget your gloves.*
*Did you test for "dO" yet?*
*Mrs. K., Rich got wet!*

Great dead men prevail but
not without the freshness
of the living,
race and gender.

Questions surface.
Answers are not as defined.
Young eyes and minds focus.

We are discovering together
and no one seems to mind
that sometimes we start over.

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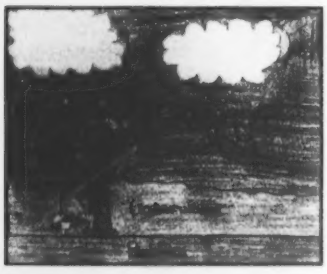

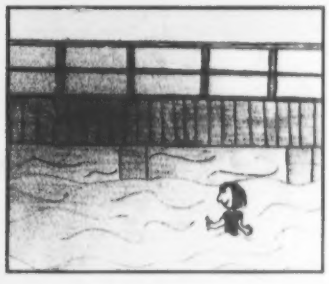

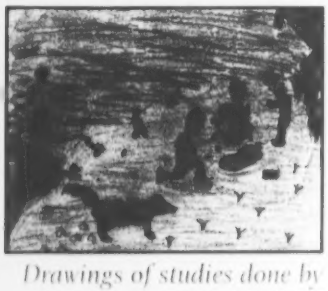

*Drawings of studies done by Terrie's students at a local lake. (From top, drawn by: Anthony, April, Bobbi-Sue, Savannah, and Ryan.)*

Prologue

*A study entitled, "Scientific Inquiry: A Journey for a Teacher and Students" by Yvette Greenspan investigates the collaboration of students working on action experiments. It all started with her own scientific research experience at the Parrot Jungle. Back in the classroom, students as individuals learned about birds to build a knowledge base, then as collaborative groups designed bird habitats. Ms. Greenspan wondered if children learn in collaborative groups and if incorporating hands-on action experiments fostered a love of learning. She gathered her data through student journals, her own personal journal, observations, and videotaping. Through her creative, hands-on action experiments, Ms. Greenspan witnessed her students building on their previous knowledge and experiences.*

# Scientific Inquiry: A Journey for a Teacher and Students

*Yvette F. Greenspan*

How do students learn?

The purpose of this study is to address the following questions:

- Utilizing fourth-generation evaluation, will students accept their roles as stakeholders and work together to negotiate consensual agreement?
- How do children learn in collaborative groups?
- How are science process skills acquired in a cooperative learning setting?
- Does incorporating hands-on, action experiments foster a love of learning?
- Given the opportunity to inquire and explore, will children take responsibility for their own learning?

In this investigation, I have undertaken research in a study of how children learn. Some educators have considered the implementation of the fourth-generation evaluation[12] as a paradigm that empowers students to take responsibility for their own learning and incorporates collaborative learning groups in the process to reach consensual agreement to solve a problem. In this study, I conducted research at the Parrot Jungle in Miami, Florida, to learn about birds, and I also learned physical science in a course that utilized action experiments. These elements gave rise to the development of pertinent science curriculum for my third-grade classroom.

*What the research says about students learning science*

At the elementary school level, as part of learning new concepts and building on previous experiences, hands-on action experiments are an important teaching strategy. "The most effective learners are actively engaged in learning through observing, reading, and experimenting."[18, p. vii] We all know that when children are engaged in learning, they are animated, excited, and

responsive.[1] Driver, Squires, Rushworth & Wood-Robinson[4, p. 3] agree, "It is recognized that learning about the world does not take place in a social vacuum. Children have available to them through language and culture ways of thinking and imaging...[I]f motivated and given the opportunity, pupils can bring ideas and prior experiences together to take their thinking forward."[4, p. 5] Finally, the authors profess, "Rather than seeing themselves as passive absorbers of information, pupils need to see themselves as actively engaged in constructing meaning by bringing their prior ideas to bear on new situations."[4, p. 7]

Constructivism "emphasizes the active agency of the learner, asserting that each learner builds or constructs his or her reality."[19, p. xiv] Cobb[2] examines two constructivist perspectives: the cognitive perspective, describing the manner in which the individual learner configures and develops knowledge, and the sociocultural perspective, describing the evolution of shared knowledge through social interaction.

Ostensibly, all knowledge is socially constructed on the basis of our experiences[22] with learning defined as the acquisition of knowledge either by study, instruction, or experience. As we acquire current information, knowledge changes, and we construct new and different understandings. Encouraging students to plan, organize, manipulate, observe, discuss, and conclude helps them understand and retain the knowledge.

Furthermore, science is a discipline that challenges the thinker. "To learn science from a constructivist philosophy implies direct experience with science as a process of knowledge generation in which prior knowledge is elaborated and changed on the basis of fresh meaning negotiated with peers and the teacher."[21, p. 7]

One of the most beneficial methods for learning science and implementing constructivist pedagogy is working in cooperative and collaborative learning groups. "Much of the enthusiasm for group learning stems from the success of groups in one aspect of problem-solving, namely, brainstorming. Research suggests that groups can build on ideas suggested by others, thereby engaging in co-construction of knowledge."[15, p. 93]

Linn & Burbules[15] further describe a cooperative learning group as one that divides a task into parts with each member completing one part of the whole project, while a collaborative learning group has two or more students jointly solving a single solution for a problem. Additionally, they purport that "in the course of...communication, students jointly negotiate understanding, plan complex tasks, explain things to each other, direct activities, contribute ideas, and coordinate actions with one another."[15, p. 92]

*Students explore and investigate together in order to complete the task.*

Group learning is a salient approach that fosters certain values and abides by the dynamics of constructivism. "Cooperative efforts begin when group members commit themselves to a mutual purpose and coordinate and integrate their efforts to achieve it."[14, p. 137] Children love to interact with their peers by listening and responding to each other's ideas. By collaboratively seeking a solution, they gain respect for others' viewpoints and learn to interpret a more accurate understanding of scientific knowledge. Developing these social skills and democratic principles prepares them for adulthood and success in the workplace.[15]

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## Designing science for my students

In this study, I designed hands-on science experiments that empowered my students to learn while they manipulated and engaged in active dialogue. At the same time, my students became more proficient with science process skills and learned to reflect and apply their knowledge in a real-world context. Guba & Lincoln[12, p. 11] note, "...the stakeholders and others who may be drawn into the evaluation are welcomed as equal partners in every aspect of design, implementation, interpretation, and resulting action of an evaluation....participants are accorded the privilege of sharing their constructions and working toward a common, consensual, more fully informed and sophisticated, joint construction."

In teaching graduate-level physical science, Gilmer & Alli[9] required teacher-students to bring materials from home to perform hands-on experiments and learn physical science content. "The idea behind these action experiments is to get the teachers in the graduate-level class to be students, asking questions, gathering data, making inferences, and building understanding about the natural world.... Action experiments are ones that cooperative groups of teacher-students select to do from a series suggested to them. The experiments call upon their experiences from living in the physical world."[9, p. 199]

## *About the school community*

In my classroom, 25 third-grade students participated in various action experiments in a collaborative learning setting. I provided various objects for the students to manipulate in hands-on, minds-on experiments. In some cases, I explained the directions to the children, while in others, the students had to explore and investigate together in order to complete the task and thus reach a solution. As a teacher-student, my experiences were similar. "Learning occurred through cooperative groups in action experiments (and) dialogue in class when members of groups explained to other teacher-students their understanding of the science content in the action experiments."[9, p. 1]

*One activity had the students simply classify the animals into groups.*

The school, with a primarily Hispanic student population, is located in a lower-to-middle-class

urban community. Within the classroom environment, there are five gifted students (four attend the in-house Gifted Program, while the other attends a nearby Resource Gifted Center twice weekly), one ESOL (English for Speakers of Other Languages) student, and one ESE (Exceptional Student Education) student. There are 12 females and 13 males; six White, 14 Hispanic, three African-American, and two Asian. Parental involvement is encouraged, and it is not unusual to find a parent visiting the classroom or a practicing intern observing the teacher.

*Group learning is a salient approach that fosters certain values and abides by the dynamics of constructivism.*

The desks are arranged in groups of four-to-five students to allow for easy accessibility to each other to share experiences. "Clusters are important because the close proximity of other students allows interchange of ideas and communication of discoveries."[17, p. 1]

I developed science units on birds and various physical science topics, which were based on Dade County's Competency-Based Curriculum (CBC) and the Florida Sunshine State Standards (SSS). Web sites for these are http://www.dcps.dade.k12.fl.us and http://www.firn.edu/doe.

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## Steps in my own research

My research was conducted in three phases:

1. Scientific research on migrating birds
2. Research on teaching physical science through action experiments
3. Action research in my third-grade classroom

*My personal research on migratory birds*

I conducted scientific research at the Parrot Jungle for the unit on birds. The Parrot Jungle is a commercial establishment with gardens that house a collection of tropical plants, trees, and flowers with exotic birds and animals. A tropical rainforest comprises most of the property along with a beautiful lake region. The goal of the investigation was to chart the various species of birds that migrate to the Parrot Jungle and then develop an appropriate curriculum for third-grade students. I expected the birds to migrate from the northern part of the United States during the winter months and reside at the Parrot Jungle for several months. I found that many bird species simply flew through the gardens on their way to Central or South America. Through this research, I learned many aspects about birds specifically related to their color, plumage, body size and shape, mating practices, and habitat preference.

*Learning physical science through action experiments*

The research for the unit on teaching action experiments was devised during a summer course in graduate-level physical science taught by Dr. Penny J. Gilmer as part of the Program in Mathematics and Science Education (ProMASE), a graduate degree-seeking program for practicing elementary and middle school teachers, taught in Miami by Florida State University. Utilizing a constructivist pedagogy through action experiments, teachers learned both physical science content and how to teach physical science within collaborative learning groups. I implemented some of the scientific content researched during the summer in my classroom curriculum, includ-


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ing changes in the physical state of water. I chose water movement, water temperature, condensation, and the water cycle for classroom study to fit with the prescribed learning goals as listed in the CBC and the SSS.

*Action research in my classroom*

This study reflects the action research I completed in my own classroom. Spiegel & Collins[20, p. 1] remark, "by action research we refer to research conducted to solve a specific problem within an organization." Dubois,[5] through his research with middle school science students, concluded that his students consistently worked together "to overcome some of the obstacles to understanding and using the difficult conceptual material involved in the rocket science unit."[5, p. 98] He maintained that working cooperatively challenged the students and motivated them to seek answers to the difficult mathematical and scientific concepts within the study of aerodynamics and space travel. By using group problem-solving strategies, students were inspired to share their experiences and optimize their learning of science.

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## My research journey

I compiled a daily journal for all three phases of the research and videotaped my students over a period of several months. The journal included my observations and students' comments.

After establishing rapport with the Director of Education at the Parrot Jungle, I began an extensive study of the birds that migrate there during the winter months. I spent long hours listening to and observing birds passing through the park, sometimes during the early hours of the day and other times at dusk. I exclusively stayed in two areas of the park—the rainforest and the lake region. I had many opportunities to interact with the Director of Education and the Project Director to discuss the migration of birds and the habitats they needed for survival. These discussions also led to identifying foliage common to South Florida. I continually communicated by e-mail to my directing university faculty member about what I was learning.

*I found that many bird species simply flew through the gardens on their way to Central or South America.*

Additionally, I was a participant working cooperatively with other elementary school teachers to learn physical science concepts. During the course of the study, the language of physical science became more sophisticated and meaningful. Difficult concepts were explained by "doing," engaging in action experiments, and using discourse as we explained our action experiments to each other. "By using the language of science and negotiating the meaning of the words, the teachers may learn science in a way that enables understanding at a deeper level."[8, p. 4]

*Assessing my students*

The purpose of my classroom study was to assess the students' knowledge and understanding of new concepts, determine if they were developing critical thinking skills, ascertain if they were equally challenged and motivated, and determine if collaborative learning was the best method for acquiring knowledge. To accomplish these tasks, I adopted several modes to determine the success of the plan.

First, I utilized qualitative research, using fourth-generation evaluation methods described by Guba & Lincoln.[12] Fourth-generation evaluation is a developmental process for judging criteria. According to Guba & Lincoln,[12, p. 50] "It is a form of evaluation in which the claims, concerns, and issues of stakeholders serve as organizational foci (the basis for determining what information is needed), that is implemented within the methodological precepts of the


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*Most children are aware of their environment and observe the smallest detail.*

constructivist inquiry paradigm." As a process, it is continuous and distinct, and the evaluator becomes a collaborator and negotiator. By empowering students and encouraging them to be stakeholders in the learning process, it creates "users of information...and forces stakeholders to confront and deal with the constructions of other groups."[12, p. 54-55]

Second, as the research progressed, it became obvious that the data I was compiling and the concepts I learned had to be incorporated into my classroom science curriculum. Furthermore, it was also evident that a major part of the project had to include observations of my students at the moment of learning, whether it related to birds or to physical science concepts.

## Studying birds in my classroom

*Before long, the students were discussing birds in situations outside of the formal classroom.*

The major unit of study in my classroom revolved around birds. The students were captivated by their new bird knowledge: habitats, body formations, means of communication, diet, mating habits. Sharing what the students already knew only made them more aware of what they did not know. Initial discussions centered on kinds of birds, where they lived, their general body characteristics, and places of migration. Because many of them could already supply bird names, one activity had the students simply classify the animals into groups, such as perching birds, owl-like birds, long-legged wading birds, duck-like birds, upright-perching birds, gull-like birds, tree-clinging birds, swallow-like birds, and hawk-like birds. Before long, the students were discussing birds in situations outside of the formal classroom. Wherever they were or to whomever they spoke, the students invariably voiced an opinion or fact about birds.

David (pseudonym):
*Look, there's one. I hear it talking!*

Ana (pseudonym):
*Where?*

David:
*Sh-sh-sh, you'll scare him away! Look how black it is and how big its wings are. It even has a long beak. And look at its toes—I count four.*

Ana:
*Let's go check Mrs. Greenspan's book to see his name!*

The students' ability to use their senses and observe the most intricate detail of the environment was obvious in their bird-watching activity and further enhanced their scientific process skills.

In order to ensure student success, I incorporated several pedagogical techniques in the science curriculum. Students completed tasks individually, in partner-pairs, and through collaborative learning groups. The goals were to promote student motivation, heighten science process skills, enhance conceptual learning, establish critical thinking, and advance negotiation among team members to reach consensual solutions to problems.

Initially, since students were accustomed to working alone, I assigned each one to compile a list of the birds that they observed on a daily basis. They drew, labeled and wrote short descriptions about those birds and placed them into a self-made bird book.


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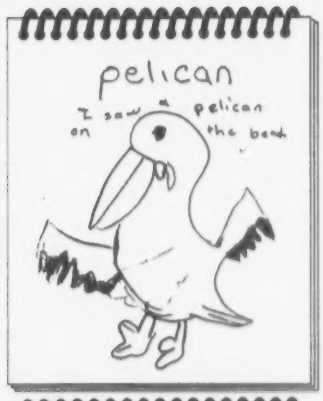

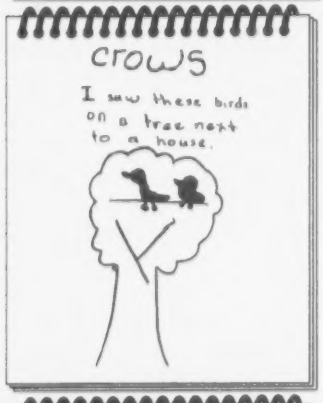


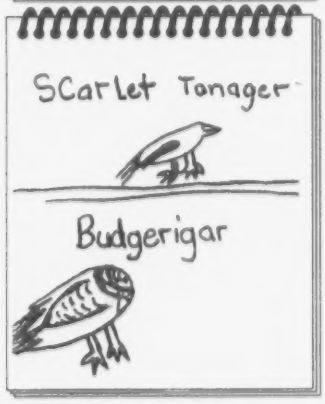


*Students drew, labeled, and wrote short descriptions about birds they had observed and placed them into a self-made bird book.*

In the next phase, students were divided into partner-pairs, sometimes teacher-assigned and other times chosen by themselves. Working in partner-pairs, the students made bird feeders from pinecones and covered them with peanut butter and birdseeds. They delightfully displayed them to their parents and installed them in the nearest tree in their backyards. Some preferred to place them on the grounds of the school and the patio outside of the classroom. Students continued to work in partner-pairs in order to understand aerodynamic concepts that were relevant to the study of birds. They created several different kinds of paper birds and measured the distances they were able to fly. They also constructed parachutes from napkins and yarn:

*Making bird feeders in Yvette's classroom.*

Donald (pseudonym) writes:

> *I learned that if a parachute has to carry a lot of weight it will fall faster. I also learned that when a bird flys (sic) it has less pressure on the top of the wing then (sic) the botton (sic)....another thing that I learned was that the higher you go the more wind there is....the last thing I learned was that without there (sic) feathers birds can't fly. This is because the feathers make a bird's body smoth (sic), very, very smoth (sic).*

The final stage resulted in collaborative teams. It encourages students to become aware of what one should know and what one should be able to do. However, it must be noted that placing a group of individuals together does not warrant or guarantee productivity. Social conflict does occur for many reasons. In this case, some students at first were aggressive and argumentative. Nevertheless, it can promote interdependence, positive attitudes, and self-esteem.[14] While beginning with partner-pairs and gradually introducing group learning may be a slow, arduous road, eventually students learn accountability, responsibility, appreciation, and respect.

In the collaborative learning groups, the students assumed the duties of one of five roles: project director, materials manager, assistant director, reporter, or team member. One of the primary collaborative learning activities was to create a three-dimensional bird habitat constructed from paper and clay. The students had some experience with teamwork but were basically novices.

*A discussion in class*

Teacher:
*Here is some clay, paper, scissors, and paste to help you design your birds and habitats.*

Student:
*What should we do?*

Teacher:
*Work together and create a habitat for your bird.*

Student:
*How do we make the tree stand up?*

Teacher:
*Discuss it with the members of your group and decide the best way to make your habitat.*

*Creating bird habitats*

The directions were uncomplicated and direct. The students soon learned that they had to take responsibility for completing the task. Many were unsure of what to do or where to begin. Some were surprised and uncomfortable with the simplified directions, and many did not understand that it was to be a three-dimensional table model. In a short time, they began working together as a team; they began communicating, listening to each other, exchanging ideas, and one member took on the leadership role. "Putting concepts into words in the context of explaining to a peer is particularly helpful for conceptual attainment."[6, p. 86]

*The students soon learned that they had to take responsibility for completing the task. They began working together as a team.*

Slowly, the dynamics of the groups unfolded, and each one took on a life of its own. In one group, the children immediately delineated their specific jobs. One knew how to make the tree, and another knew how to make the mountain; they equally shared their responsibilities. In another group, they decided that they would all work together on making the lake/river/ocean; they preferred working as one. However, in another group, while the majority of the members were individually involved in their own task, one member said, "They won't let me do anything!" and that child simply refused to participate. In this instance, each learner was pursuing his or her own personal goal. According to Marzano,[16, p. 140] "it is when we are trying to accomplish a personal goal that we are most likely to have a need to plan, manage resources, seek accuracy, work at the edge rather than the center of our competence...." At that moment, I asked the student to explain the situation, and after listening to the problem, I casually mentioned to the group that everyone had to have a job. One of the

*Students began working together as a team; they began communicating, listening to each other, and exchanging ideas.*



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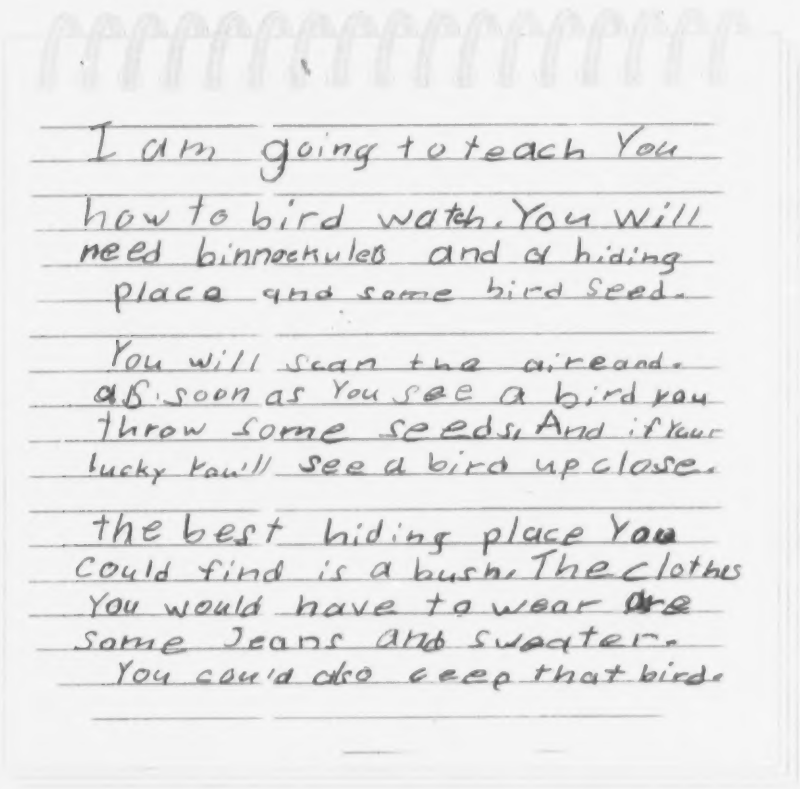
*In some cases, I explained the directions to the children, while in others, the students had to explore and investigate together in order to complete the task and thus reach a solution.*

students, unexpectedly, and in an indifferent manner, assigned a task to that child. For the moment, the conflict was resolved, and the team appeared to negotiate towards mutual agreement, working together in an agreeable fashion.

While instructing young learners, it is beneficial to integrate the disciplines and make learning relative to their world. Small groups of students designed interactive reports on the computer and shared them with their classmates. Creativity, imagination, and cooperation were integral elements in completing the task. "Many students struggle to understand concepts in isolation, to learn parts without seeing wholes, to make connections where they see only disparity, and to accept as reality what their perceptions question."[11, p. 7]

In a language arts assignment, the students had to write a "how-to paragraph." Frankenstein[7, p. 69] reports, "Writing because the writer and others can see it, allows one to explore relationships, make meanings, and manipulate thoughts; to extend, expand, or drop ideas; and to review, comment upon, and monitor reflections...." The following is an example of a student making a connection to his world; grammar, punctuation, spelling, and capital letters are the work of the author, R.R:



I am going to teach You how to bird watch. You will need binnockulers and a hiding place and some bird seed.

You will scan the aireand. as soon as You see a bird you throw some seeds. And if Your lucky You'll see a bird up close.

the best hiding place You could find is a bush. The clothes You would have to wear are some Jeans and sweater. You could also keep that bird.

In addition, the CBC outlines several physical science concepts that Miami-Dade County requires third-graders to learn. One example is the three forms of matter. Taught at the very basic level and explored in collaborative learning groups using a hands-on weather station, I chose to teach the states of matter using meteorological concepts. Collecting weather data daily, the students delivered the weather forecast to the entire student body through an in-house television news station.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Experiments related to mass and volume also helped the students gain insight into the properties of matter. I assigned jobs to students in collaborative learning teams that allowed the children to make predictions, compare masses of many different kinds of solids, and draw conclusions from the collected data. Estimating and measuring the amount of water a container holds and repeating several trials aided the team in reaching a group consensus on the volume an object can hold. The students organized the data with charts and learned about experimental variables and their effect on the results of an investigation. Comparing the data from several teams allowed the "scientists" to get different results from doing the same experiment. The aim of the study was to validate the students' work.[13]

Students participated in multiple experiments related to the movement of water, in a positive structure of interdependence.[14] Students in collaborative teams especially enjoyed exploring water molecules moving through a maze, creating a mini-water cycle in plastic Ziploc® bags, and playing the role of detectives in a chromatography mystery. Chromatography is a technique used to separate mixtures. The students place water as the solvent on paper coffee filters. The students noted that as the solvent passed through the test substance, some of it was attracted to the solvent and flowed up the paper medium. They concluded that different types of molecules are transported different distances, causing separation of the components. As detectives solving the mystery of the ransom note, the following comments were overheard:

Group A:

> *Look at the colors on this ransom note! It is blue and yellow. It couldn't be Jack-O-Lantern; it doesn't have orange!*

Group B:

> *It turns yellow. All of this is a regular marker. Look, the colors are going up! It smells bad!* (smelling the ransom note) *Look* (pointing), *it's the highest one!*

Reading a thermometer is another third-grade learning objective. By comparing the temperatures of ice water and boiling water, the students learned to write the temperatures in Fahrenheit and Celsius. Students also observed how evaporation and condensation occur. They were delighted to observe the "smoke" rising from the beaker filled with boiling water, and when the water cooled, they were able further to observe the water droplets condensing on the inside of the glass. Each and every one had identified the concepts of evaporation and condensation because they had previous experience with them in real life. Constructivism "is an attempt to refocus attention on the prior ideas, experiences, and habits of thinking."[19, p. xv] Each team collated the thermometer readings onto a class-size chart, encouraging further discussions on hypothesizing and variables that affected their results. Ultimately, each group created a bar graph for the whole group to compare and contrast.

To further develop their science process skills, the students added salt or sugar to ice water and boiling water. Over a one-week period, the collaborative learning groups compared and analyzed observations, such as visual and tactile, and then wrote conclusions that were consensually negotiated

*As a result of consolidating action experiments and collaborative learning groups, students' vocabulary became more sophisticated; they spoke as young scientists.*

by each team. "They learn from each other; they are stimulated to carry out higher-order thinking; and they experience an authentic intellectual pride of craft when the product is more than what any single member could create."[3, p.86]

In addition, it is evident in responses to the question, "What is weather?" that students are learning to develop their science process skills through observing, inferring, hypothesizing. (Grammar and punctuation are those of the authors.)

David (pseudonym) states:

> *When I started to study weather I really liked it. It was one of my favorite science subjects. I learned new words and I even leanred (sic) about the water cycle. I learned alot (sic) more than I thought I was going to.*

Virginia (pseudonym) notes:

> *Weather is fun when you study about it because you can use weather tool (sic)....Their (sic) are diffient (sic) kinds of weather, like perspirtion (sic), and claim (sic). I measer (sic) the morster (sic) in the air every morning outside our classroom. I learned about wate (sic) vaorer (sic) to (sic) and the water cycle.*

Children's views towards the weather elements changed significantly. For example, they were no longer confused about the process of the water cycle, nor did they misinterpret such terms as *condensation* and *evaporation*. Moreover, they were able to predict and forecast weather based on their findings about clouds, air temperature, barometric pressure, and relative humidity readings, and they were motivated, enthusiastic, and eager to chart their data daily.

As a result of consolidating action experiments and collaborative learning groups, students' vocabulary became more sophisticated; they spoke as young scientists, and they were more willing to take a risk in expressing their knowledge verbally and in writing. Hands flew up in whole-group discussions, and mouths moved rapidly in team meetings, with everyone expressing scientific phenomena typically unheard in a third-grade classroom.

*Displaying and sharing clay models of birds.*



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## Conclusions from my research

Studying birds gave the students insight into many things they already knew but had not previously communicated. "The teacher's role will no longer be to dispense 'truth' but rather to help and guide the student in the conceptual organization of certain areas of experience."[10] As the research at the Parrot Jungle flourished, I became more enthusiastic. It was clearly reflected in my teaching, echoed by my students. Many became totally committed to learning about birds. Some bought birds as pets; others videotaped local television programs about birds; many became loyal to weekly bird-watching. Marzano[16, p. 1] aptly asserts, "We know that effective teaching mirrors effective learning, yet as educators we have not mounted a serious effort to organize teaching around the learning process."

By incorporating hands-on, minds-on activities, I augmented basic skills and integrated science process skills. Basic skills—like observing, communicating, classifying, measuring, inferring, and predicting—led students to exhibit curiosity, questioning, and interpretations of the world around them. Action experiments were the integral component for achieving success.

Integrated skills such as identifying variables, constructing tables and graphs, analyzing investigations, and constructing hypotheses challenged the students to think critically. Students developed science process skills by engaging in many opportunities to practice them in various contexts and in different content areas.

Since learning the most difficult physical science concepts during the summer by engaging in inquiry, analyzing data, and sharing with peers, I easily conveyed my newly found understandings and knowledge to my students. Not having previously studied or researched at such levels in chemistry, I was indeed comfortable now in teaching those complex concepts in the language of science.

Having first-hand experienced scientific research and the opportunity to interact with scientists in the field further gave me the confidence and the ability to incorporate multiple areas of science content into my teaching. Students provided evidence of understanding in their drawings, particularly about birds, which contained extensive details, such as plumage and coloration, behavior, habitat preferences, and voice sounds. Interestingly, the children continue to learn more and constantly request more science in the daily curriculum.

*Visiting the Wild Bird Rehabilitation Center.*

Providing a setting conducive to sharing, collaborative group learning nurtured cognitive skills, motivated students to solve problems, established consensual decision-making, and fostered a love of learning. The students also took pride in sharing

what they knew, conveying their enthusiasm. Entering into discussion with preconceived ideas and various experiences, the children quickly altered their constructs and created new ones based on the opportunity to engage, inquire, and communicate with each other. Soon, the students were in control of their own learning and looked to me as the guide rather than the sage in their quest for new knowledge. Over a period of time, they gained confidence in their ability to take responsibility to think and problem-solve, gaining the needed support from their peers. As it evolved, the teacher's role became a secondary rather than a primary force within the classroom.

As Tobin et al.[21, p. 7] remark, "The major curriculum challenge for teachers is to focus on student learning with understanding rather than to treat content coverage only." On the one hand, constructivism stands in contrast to traditional methods of teaching, but, on the other, it helps learners to internalize and transform new information for their own use and understanding.

*A version of this paper was presented at the annual meeting of the National Association for Research in Science Teaching on April 20, 1998, in San Diego, California.*

## Yvette F. Greenspan

Years Teaching: 22

Present Positions:

- Fifth-grade teacher, member, and secretary of Educational Excellence Council at David Fairchild Elementary School, Miami, FL
- Vice-President and newsletter co-editor for Dade County Science Teachers' Association
- Teacher/consultant/leader for Urban Systematic Initiative of Miami Dade County Public Schools
- Graduate doctoral student in science education at Florida State University

*"Having first-hand experienced scientific research and the opportunity to interact with scientists in the field further gave me the confidence and the ability to incorporate multiple areas of science content into my teaching."*

*"I spent long hours listening and observing birds passing through the park, sometimes during the early hours of the day and other times at dusk."*

*"As a result of my bird research, I implemented a major unit on birds in my classroom. The students were captivated by their new bird knowledge. I realized that they knew a lot more than I had anticipated, and it was only necessary for me to guide them in the direction of their interests."*

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## Prologue

*Marcie Bosseler's research* "Learning and Growing as a Scientist and Science Educator" *starts with her personal experiences in the field that began with her own journey of learning. First, she learned the nature of science by assisting Dr. Grace Giffin in the Florida Keys, tagging the* Opuntia spinosissima *cactus, then later by learning the methods used to mark and release butterfly populations in a botanical garden. In her classroom, students became thinkers, developing emergent theories on scientific concepts. She wanted to know if her students would benefit from and engage in science more after experiencing authentic scientific research. By learning to be a listener and a participant, both teacher and students became empowered by scientific discoveries they made together.*

# Learning and Growing as a Scientist and Science Educator

*Marcie L. Bosseler*

*"A scientist is someone who thinks about science!" Melanie, age 6*

## I begin to evaluate my existing teaching

Though not everyone will become a scientist, as we enter the 21st century, an understanding of the basic ideas of science is essential for anyone living in our world. We all make daily decisions that may enlighten or burden society, depending on our ability to use information effectively.[12] Realizing that children embark on the study of natural phenomena with ideas already formed from their backgrounds and experiences, I sought a method of teaching, driven by a form of action research. Action research is a strategy that assists educators in solving problems, enhancing decision-making practices, and viewing situations through critical thinking.[10] My objective was not only for my students to continue learning through existing thematic strategies but to assess my skills and inquiry methods as I tried to improve my practice.

*Though not everyone will become a scientist entering the 21st century, an understanding of the basic ideas of science is essential for anyone living in our world.*

According to Guba & Lincoln,[8] my students, as stakeholders, are empowered in their learning with respect to the methodology as well as their constructions. I must learn what the various stakeholders' competing constructions are so that I can communicate them to all of the stakeholders. As the evaluator and collaborator, I become a change agent. Am I driving forward with my eyes on the rear view mirror? Or am I really working toward creating an environment in which science is a less intimidating, more realistic, human endeavor in which everyone can be involved?[9]



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I am a teacher. I was not originally trained as a scientist, but now I am beginning to think like a scientist and feel I am becoming one. My students think they are scientists, too! My class consists of intellectually gifted kindergarten through third-graders who attend my center two days a week. My goal for the gifted program is to include enrichment strategies such as critical thinking, creative thinking, personal growth, leadership development, communication, research, and problem-solving. Scientific exploration and inquiry are the basis for the processes I use to help my students construct their own knowledge. Successful thinking is more important than "correct" answers. "Successful thinking should be rewarded...."[14] Because I teach a special population in an enrichment environment, I can select the thematic units, directing those within strategies of gifted educational models.

*A group of Marcie's students testing density.*

In my teaching I try to connect my students' pre-existing knowledge, so I can provide opportunities for them to learn. After 28 years in the classroom, I continue to be excited about teaching. To me, and I hope to my students, learning is a journey—not a destination.[2]

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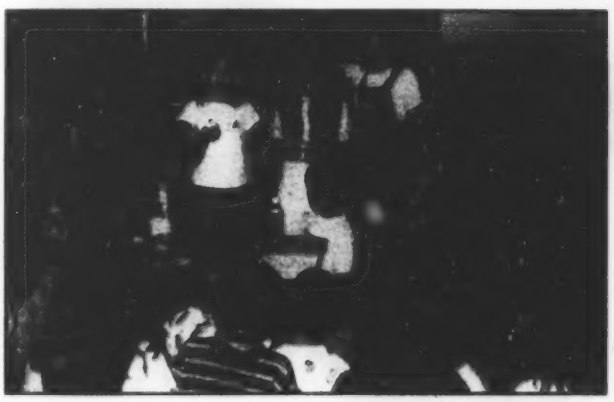
## Positivism *versus* constructivism

In the traditional classroom, the positivist tries to "pour" knowledge into the student as if each student is a "blank slate" or *tabula rasa*, etching information on his/her students' brains, without linking to previous experiences. The positivist teacher seeks the correct answer from the students to validate student learning[12] and views assessment of student learning as separate from teaching. Assessment in a positivist teacher's classroom occurs almost entirely through testing with students working individually. Such teachers are didactic disseminators of information.



*Science Mentors.*

To understand constructivism, educators must focus attention on the learner. Let us compare a traditional classroom to my developing constructivist classroom. In the constructivist classroom, the teacher presents the curriculum, emphasizing the big concepts, with the students as the thinkers with emergent theories about the world.[2] Students primarily

work in groups, and the teacher values it highly when students pursue their own questions. Constructivists rely on primary resources of data and manipulatives. The teacher behaves in an interactive manner, seeking students' points of view and questioning in order to understand their conceptions. The teacher interweaves assessment of student learning with teaching, observing students at work, utilizing student exhibitions and portfolios.[2]

Basically, in my classroom, I focus my attention on the learner. I feel that, with my help, my students begin to know their world. As a developing constructivist classroom teacher, I empower my students to follow their interests, make connections, reformulate ideas, and sometimes reach unique conclusions.

*The teacher can help the students develop the roots of knowledge, but also empower them with wings.*

Tobin describes learning in terms of a journey between cultures.[15] A student's first culture is his/her personal language and common sense in terms of his/her lived life. The second culture is that of the classroom, where the teacher provides opportunities for students to access resources for learning. These resources include a knowledgeable teacher, a set of peers, books, appropriate equipment, and materials. The third culture is transitional, represented by scientific knowledge. Thus, it is a goal to know science as scientists know it and act accordingly.[15] Guba & Lincoln[8] maintain that the fourth-generation evaluation mandates that the evaluator move from the role of controller to that of collaborator, in the spirit of shared mutual responsibility, as a change agent for the stakeholders (i.e., the students).

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## Teacher, student, learner

Teaching staff development courses for gifted certification provided me with my own refresher and current teaching doctrines; as a result, I redefined the contributions of Joseph Renzulli[11] and John Dewey,[4] who stressed the relevancy of students' interest in framing curriculum. As part of the Florida State University doctoral program, I have had the opportunity to learn while re-examining my own teaching. After learning about constructivism, I felt I already possessed many of the traits of a constructivist teacher. I have since learned that I, too, need to experience knowledge first-hand.

*Density experiments.*

My first semester as a graduate student in science education was quite an enlightening experience. I began to examine my own teaching doctrines. I know that learners must construct their own knowledge as the theory of constructivism purports; the learner does not receive knowledge but actively builds it, and the function of cognition is adaptive, serving to organize the experiential world.[7] As I started graduate school, I asked myself the following three questions:

- Am I maximizing opportunities for students to express their points of view, reveal their conceptions, reflect on their conceptions, learn from other's ideas, and most importantly, grow intellectually?
- By experiencing the nature of scientific inquiry and the processes of science through authentic research, will I construct understandings differently about what science is and how to teach it?
- Will my students engage more in science having experienced authentic scientific research?[7]

*Marcie and a scientist.*

Indeed, as part of my graduate program, I became a teacher-student, simultaneously teaching in my own classroom and learning as a student in a constructivist physical science classroom.[5] As a student, I worked in collaborative groups, exchanging dialogue in the classroom and on the Internet with other practicing teachers who were co-learners with me. I used the discourse of science in the classroom, on the World Wide Web, and in my own elementary school gifted center.

*I found each morsel of scientific know-how fascinating.*

In my own coursework, the action experiments conducted in class revealed many things. Several in the class were the "I-don't-do-science" teachers, although our instructor encouraged us to participate, question, and redesign action experiments to bring out the elements of inquiry. Bringing in items from outside the classroom allowed us to become intimately involved in the process. We were contributors, not merely users. Once again, the language of science flowed throughout the class as each of us evolved as students in our own unique way. A visit from another physics professor swayed my confidence and focus as he attempted to "teach" me on a knowledge level, never altering his approach as he repeatedly tried to explain about sound waves to me without my comprehending his language or his way of thinking. I had become accustomed to an approach that began to ease my mind of doubt or failure. For weeks, we shared in the bounty of scientific discovery. I found the magnet study, taking a can, string, paper clip, and magnet to produce a "magic" feat fascinating. The carry-over to my own classroom made it even more enlightening.

## *My journey as a botanist*

My growth as a scientist did not terminate with the physical science course but went further as I worked with a research conservationist from a botanical garden. Here, too, I was a learner and experienced the journey into new perspectives and knowledge in a real-science experience. Communication with other scientists at the site allowed me to peek into their world of problem-solving and scientific reasoning. The language of science evolved for me and my students as we became hands-on and minds-on scientists!

### *The beginning*

I began my research by meeting with Dr. Grace Giffin regarding the research she performs at The Garden, an affiliate of the Center for Plant Conservation (CPC), the only national organization solely targeted to conserve plant species. The Missouri Botanical Garden is the headquarters for 25 botanical gardens and arboreta. The 16 represented regions collect and



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maintain critically endangered plants. As a participating member, the Garden brings plants into cultivation, propagates them, and then reintroduces them into protected areas. This is called *ex situ* research, accomplished under Dr. Giffin's efforts.

(Excerpt from my journal):

*I did my homework by purchasing* Ecosystems of Florida *by Myers & Ewel,* The Naturalist *by Edward O. Wilson,* Florida Trails *by Florida Advisory Council on Environmental Education and began an Internet Web search. This final reference proved to be the most conclusive!*

Dade County has a greater number of endemic plants than any other county in Florida. Most of these are found in the pine rocklands, an area endemic to the state. Plant endangerment is linked primarily to invasive exotics and loss of habitat due to ever-growing population and construction. As the native pine rockland deteriorates, it is necessary to put plants back in areas which are historically protected. Reintroduction is one of many approaches in research management. Genetic sampling guidelines are used for research, education, or outplanting (i.e., selected sampling replanted under controlled conditions). Soil-free mixtures are used for the outplanting of the specimens. The best way to protect the widest diversity of plants in their native habitats is collecting them from natural varied sites.

*Plants and trees are easily identified with genus/species, so I've become more familiar with the language of botany.*

Presently, Dr. Giffin is working with a cactus, *Opuntia spinosissima,* to expand the conservation collection of South Florida taxa. This is done *ex situ,* which means that plants are collected from multiple sites and populations in the wild, developed, and then reintroduced in a natural environ. Care is taken that plants are genetically different, so genetic origin is maintained. Botanists go into the area and document what exists in the territory. The plants are genetically unique. Before the intended project is begun, monitoring data are collected to observe and record seasonal and biodiversity changes over time. Monitoring includes seasonal observations of such things as bugs, drought, and biodiversity. Only in rare cases would the entire plant be taken. Back at the Garden, a research plant identification system is used, and the data are placed in the Accession Book. This book and the stored volumes contain the Garden number, genus/species, exact date of collection, number of pieces, the plant part (i.e., seed, pad, leaf, whole plant), condition of plant part, location where collected, and the source. The plant part is tagged with number and date. This inventory has been maintained since the 1980s. Soil-free mixtures are used for outplanting the specimens. Reintroduction of the plant into native habitats is similar to acquisition methods. Monitoring continues in the native plant community. In the permanent collection, original plants are used for propagules. After viewing the collections of the Garden's Endangered Species Program, I have a greater appreciation and awareness of species extinction and the extent to which conservationists are pursuing their propagation and protection. Plants and trees are easily identified with genus/species, so I have become more familiar with the language of botany!

*Preparation and anticipation of my first field experience*

(Excerpt from my journal):

*My only field experience with Dr. Giffin is to be two months from now; therefore, I am using this time in a literature search for related biodiversity information, reading, and surfing the 'Net. I am dis-*



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*appointed that my field experience is limited and two months away. Like any learner, I feel knowledge gained through my direct involvement in the learning will be far more meaningful to me. I am gaining insight into the procedural methods used by scientists.*

The site in the Keys is one where Dr. Giffin and her team have outplanted the *Opuntia spinosissima*. These are native cacti, imperiled and growing on public-owned property that has a management plan. We will focus on the reintroduction of native species that are imperiled and included in the biodiversity of the area. "Rockland" refers to the area in the Keys, right off Card Sound bridge, which is called the Upper Keys. The rockland ledge is different at my school and around the Garden. There is a rather large area of limestone, called the Miami Rock Ridge that extends from Miami to Homestead and narrows westward through the Long Pine Key of Everglades National Park. The Keys are almost entirely the outcrop of the Key Largo limestone.

(Excerpt from my journal):

*Saturday, and I'm on my way to the Keys, involved as a scientist at last! I can share the true meaning of contextual learning as I become a part of the efforts to expand* ex situ *conservation collections of* Opuntia spinosissima. *As the morning dawned, I checked and rechecked my gear. The world of the true adventurer is foreign to me, i.e., backpacking and experiencing the great outdoors. This was going to be a scientist's field trip; I knew that for sure!*

*I'm on my way to the Keys, involved as a scientist at last!*

Dr. Giffin had faxed me a memo containing a suggested list of supplies for the field work. The list included: backpack, hat/bandanna, long pants (cotton), T-shirt and long-sleeved cotton shirt, sturdy hiking shoes/boots, poncho/rain gear (if rain is predicted), sunscreen, insect repellent, water (1-2 liter bottle), field notebook and pen, camera, binoculars, and hand lens.

(Excerpt from my journal):

*So, now I even look like a scientist! Thoughts of what lay ahead in the dense hammocks, I added to this list the following: compass, flashing emergency light, an apple, a sweatshirt, and a portable phone. I chose not to wear a long-sleeved shirt and later realized the wisdom of the suggested shirt as protection against mosquitoes, trees, and potentially poisonous underbrush.*

*So, now I even look like a scientist!*

To reach the upper Keys, one travels through a diverse area, with stretches of sawgrass, estuarine, and mangrove communities where one can occasionally view the ocean on either side of the road. Landmark fishing camps, a few isolated eateries, and the habitats along the way make the drive a solitary yet enjoyable one. After the toll bridge, a fork in the road leads into the more dense hammocks on both sides of the road. I finally arrived at the Florida Department of Environmental Protection, Division of Recreation and Parks office.

Dr. Giffin greeted me and introduced me to our two other companions: Joe and Janet, two uniformed Everglades Park rangers. We immediately departed in Janet's car as she swiftly drove to a pre-determined site. Dr. Giffin was attired with proper gear, including a large compass, a backpack, and carrying a small utility bag with orange soil-marking flags.

*Learning how scientists communicate*


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(Excerpt from my journal):

*I was not a part of the conversation and, in fact, did not contribute much the entire trip. It was somewhat of an enjoyable departure for me to just listen. I stayed a listener, and this carried over so that I feel I became a better observer, too. These were working friends, who discussed the department "stuff" as well as the condition of the site we were approaching, the Key Largo Hammock State Preserves.*

The scientific language was interesting to note, and I thought about this quite a bit. Each of us carries a language that defines our profession and requires a knowledge of some kind to translate. I was so glad that Joe had come along, giving lots of chatter, the general goings on at the Key Largo park, which is his and Janet's workplace. Joe kept referring to the infestation of the sapodilla growth altering the pine rockland native species. The sapodilla, a large evergreen tree, *Achras apota*, bears fruit and chickle. It is not a native species. Joe's solution to infestation problems was to remove exotics out of high-priority areas first. Dr. Giffin appeared to agree with his analysis.

*I was hearing the language of science!*

(Excerpt from my journal):

*I enjoyed listening to the science of the group's shared language and was impressed that they did not stray from the issues and tasks at hand in their discussions! I was hearing the language of science!*

*The privilege of rank—we entered a "No Trespassing" area of this pristine, 11-mile park hammock.*

The privilege of rank—we entered a "No Trespassing" area of this pristine 11-mile park hammock. There had been 22 mm of rain the previous day, so our surroundings were quite damp, but I was comfortable with the wonderful earthy smells of leaves, trees, and water! The concern for the *sappodia* invasion of undisturbed hammock areas was repeatedly suggested by Joe. We were following trails laid out by Janet and Dr. Giffin a year ago. These were plastic ties on trees forming something of a path, which we were easily following.

*Collecting and tagging the cacti*

The original sites were marked by heavy metal tubes, painted bright orange and wedged deeply into the ground. These were recorded using a global positioning system, commonly called GPS. We came upon our first site recognizable by small metal flag posts, probably two dozen. I observed as they, in teamwork fashion, measured the length, overall width, number of "pads" (i.e., branches), and overall condition of the cactus. These have been experimentally reintroduced into selected natural areas. The samples were originally gathered from the field, numerically tagged and recorded, potted and sustained at the research center, then reintroduced to enhance wild populations in historically appropriate and protected natural areas. Dr. Giffin recorded the data for each sample. The entire site was infested with snails on the *opuntia*. Joe observed that the sparse overlay of spines allowed the snails to have more space, thus becoming a desirable habitat for them. The scientists described the condition of the cacti with words like: *significant, poor, minimal, apparent, obviated,* or *good*. None were described as *excellent*, and those that had died were described as *fallen* or *not observed*. This first site was forest-like, a native hammock.

(Excerpt from my journal):

*I found each morsel of scientific know-how fascinating. I sensed the*


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*respect not only for nature's beauty but also for nature's protective fury when ignored.*

*More sites to tag and collect the cacti*

The second site was in a buttonwood area, which we reached by going deeper into the park. This is land that is protected by the state and is historically important. A huge cistern, presently helping the mosquito population expand, was once part of a homestead. Imagine what it must have been like to live in this pristine area. Incidentally, we saw only one bird, no animals, a few spiders, and several empty soda bottles the entire trip. The cacti here were generally healthier, and there were no snails on any of the plants. Unlike the hammock, it was warmer here as the sun shone through open patches of the canopy. Dr. Giffin mentioned that the qualitative data we were now taking would be repeated four times every year.

We hurried purposely through the hammock, then approached another area of the hammock where we repeated the data recordings.

(Excerpt from my journal):

*Finally, at this point, I was involved in the data collecting, either measuring or recording. I reflected how learners must feel when they are withheld and then finally given permission to actively participate in science! Meaningful learning!*

The three sites visited here were larger, requiring our having to retrace our markings to be certain all plantings were recorded. Then, Dr. Giffin would put a smaller red stake next to the existing one to check that we had recorded it. An idea evolved—let's put the smaller red stakes out immediately; then, as we collect data from each, we will remove the red, thus not having to retrace our steps.

(Excerpt from my journal):

*I thought it such a "human" kind of touch that scientists collecting data are never so set in a systematic approach that they can't look for an easier and more efficient way to conduct their search!*

We must have collected approximately 60-70 taggings. All in all, I think everyone was pleased with our findings and will return in three months to gather more data. I would certainly enjoy and benefit from other field trips, if it is possible to arrange.

(Excerpt from my journal):

*I feel that this experience has enlightened me as I, too, am the student and learner. More importantly, I, the constructivist, am experiencing didactic teaching, which I find is a barrier to my learning.*

Shortly after my trip to the Keys, I set up a trip to the Garden. I was hoping to reconfirm or reconsider alternatives to my assessments of scientific learning by visiting Carrie Brock, Educational Director, whom I had met two summers ago when I attended a botany workshop at the Garden.

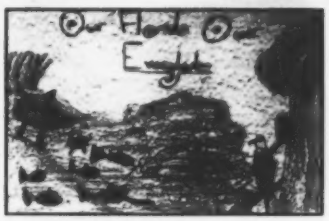
William Lyman Phillips designed the botanical garden, which opened in 1938. Donor Robert Montgomery had conceived of the garden as a private undertaking. He teamed with David Fairchild to develop the site near the

*Botanical garden experience*

bay and cool ocean breezes. Native plants were brought in, with some having to adapt to grow in the sand and limestone soil. A limestone ridge, dating back to the Ice Age, runs through the 83 acres of the garden. Lakes were dredged to fill the marshlands and plants arranged by species around the lakes. The various levels and striations of the land are part of the coral rock ridges for draining purposes. All in all, a beautiful site!

*Being a learner on a fourth-grade field trip*

I joined fourth-grade students from another school on their field day, and they were exceptionally curious and excited to be here. Having joined their group, they looked at me rather curiously but welcomed this stranger. I found it was fun reversing my usual role of being the teacher, instead being another learner in the group. One student, Dustin, repeatedly mentioned "native species," plants natural to the area, and "exotics" such as the *malaleuca*, which are trying to invade native growth. The *malaleuca* was originally planted in the Everglades to help dry up the swamps. Unfortunately, this proved to be a devastating decision. The *malaleuca* has now taken over, impeding native plants from surviving. Natives like gumbo limbo, live oak, bald cypress, buttonwood, sabal palm (Florida's state tree) were all living peacefully in their environment prior to the *malaleuca* invasion. There was a section sited with small red flags similar to those used by Dr. Giffin to designate plantings of *Psuphenia*, endangered palms. The seeds were collected and propagated in native habitats at the Garden. All this conversation reminded me of my trip to catalog the cacti in the rocklands.



*Student drawings.*

Our tour guide was a native Miamian, living her life in the Homestead area, and had much to offer. "Be my detectives. I'm going to give you clues." Her approach had the group in the palm of her hand. After giving each child a small hand lens, she took them into the solution hole made of oolite minerals made by calcium and water dissolved over hundreds of years.

(Excerpt from my journal):

*She brought her life experiences—the students brought their natural curiosity! Together, they made science learning magic!*

I assisted the students who were potting the firecracker and royal palm cuttings. They welcomed another set of hands, and I was happy to help! I was especially grateful to Carrie Brock for allowing me to "shadow" her, applauding her genuine pride in sharing the Garden's botanical wealth and her outstanding hands-on teaching skills. Each of us felt ownership in our experience.

*She brought her life experiences—the students brought their natural curiosity! Together, they made science learning magic!*

(Excerpt from my journal):

*I felt like the fern, resurrected and growing more toward being a scientist, ready to explore with my students who have so much ahead of them to discover, too. I was so thrilled to be able to learn about this kind of scientific investigation right there at the Garden.*

*Observing butterfly research*

Near the potting area in the Garden, I spotted a young man armed with a butterfly net and a clipboard, writing numbers on a very small butterfly's wing. I knew about the Monarch Watch, having requested the "stick-on" taggings to chart their southward migration. I talked to this young graduate student from Richard Wagner's birthplace at the University of Bayreuth. Kornmaier Bernd was staying at the Montgomery residence while doing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research on the Atala butterfly (*Lycaenidae*-family, *Eumaeus atala*-genus, species). After catching them in a butterfly net, he was using a permanent pen, tagging the underside of these newly hatched butterflies, recording data, and then immediately setting them free again.

(Excerpt from my journal):

*And so the language of science begins again!*

Kornmaier told me about a method called MRR (i.e., Mark-Release-Refine), as he used it. Using the MNA (i.e., Minimal-Number-Alive) system on his computer, he could calculate the whole population. He estimated that about 300 butterflies altogether were living on the highly poisonous cycad plants, *Zaimia pumila*. Watching Kornmaier catch the small black and orange-bodied butterfly with shiny blue markings on its wings was fascinating. I observed as Kornmaier wrote the numbers very distinctly so he could easily read them. One thing that I found fascinating is that the caterpillar and the butterfly of the Atala is so poisonous that a spider will throw it out of its nest, rather than risk its effects. Despite the fact that this butterfly is so poisonous (or perhaps because of it), research scientists are presently seeking a cancer cure with the Atala butterfly.

*The "Conclusion" of the scientific method should be stated as the "BEGINNING"!*

(Excerpt from my journal):

*The "Conclusion" of the scientific method should be stated as the "BEGINNING"! Scientists conclude by turning a new page and starting anew!*

I was so appreciative of Kornmaier's time! Like Dr. Giffin and others, he affirms that he doesn't have all the answers and might have to readjust his hypothesis totally, but that is not going to deter him in the least.

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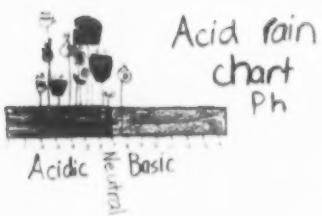
## Our GLOBE project




*Learning creates changes in students*

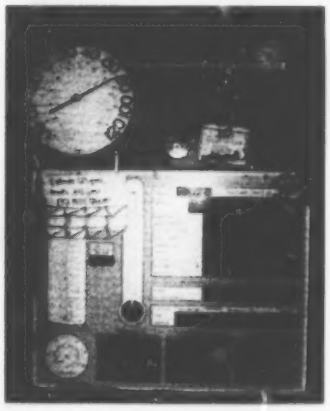
GLOBE (Global Learning and Observations to Benefit the Environment) is a grant-awarded, schoolwide science program (http://www.globe.gov), in which students become meteorologists by gathering daily weather data from a GLOBE Web site and sending it to scientists at the University of Colorado. The chief scientist for GLOBE visited my school, and he talked about the interconnections of all things in science and linking of all systems. His scientific language was inclusive of all science. Most importantly, using the scientific method only reinforces the notion that conclusions reached become new data for the next step into inquiry and investigation. Meeting other scientists gave me another glimpse into authentic science research.

*PAL GLOBE Team with international guests.*

I began to seek changes in the process of my students' learning. Why not include the hands-on experiments integrated as a part of the curriculum, bringing into sharper focus the systematic changes that evolve with my students? I became

*Plotting wind study with Beaufort Scale using a Wind Speed Meter.*

*Recording GLOBE weather data on a computer.*



*Part of the "discovery zone" in Marcie's classroom.*

more of a listener, a co-participant sharing scientific language with my students. A body of facts is not uniquely interpretable in terms of one theory. As Guba & Lincoln[8] maintain, credibility is constructed between the students in my class (i.e., the stakeholders) and me, their teacher (i.e., the evaluator). The first step in empowerment is taken when all the stakeholders are able to provide input shaping the strategies and the evaluations.[8]

My room is becoming more of a discovery zone as I have developed the reputation of being "Mrs. Fizzle" on the Magic Schoolbus! We had a debate about a prediction of El Niño within our community, and a recent tornado and turbulent weather were part of the discussion. Yet, the conversation itself invited many questions and extended research on the students' part, asking, "Can we do science experiments during the Lab time?" The Lab time is an independent hour in which students select independent activities. Several students in each of my classes seem to have the same idea—forming a science club to conduct and share experiments. What I see evolving is the mirroring of my teaching reflected in them. Who could imagine anything more gratifying than this? After we conducted an experiment illustrating density, one group showed the class the way they took water, colored it with food coloring, and then added yellow-colored chalk. The density layers appeared. I have not objected to the experiments but have insisted that they plan and discuss how they will present the experiments and their findings.

One surprise was a play that two of the girls wrote and produced. The play was about a mad scientist who has made a potion to blow up the world. Another student, Essa, suddenly appeared and wanted very much to be in the play. She is the only African-American girl in the class, and previously had not wanted to join in any of the temporary, self-proclaimed class groups. Suddenly, she was trying to fit into our circle of scientists. The play was adorable, and I allowed them to put on the play for the other center classes. Incidentally, we have also found another talent that Essa possesses—acting!

June 7, 1997

Dear Mrs. Bosseler,

I would just love to be one of the weather girls this coming year. I would like to be a weather girl because..

1. I love to help people.
2. I can warn people about bad weather.
3. I will not only help kids but also help teachers and others at Palmetto.

If I am given this chance, I promise to do my very best as a weather girl.

Sincerly yours,
Erica

I became part of the community of learners

Experiencing science as I have recently, has allowed me to open my eyes wider to what surrounds me. I am gratified when my students display change, as Charles Darwin did, when he was forced to alter his thinking radically, not only in his own discipline but in virtually every area of human activity.[8] While



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experimenting with water recently, I was perplexed by the failure of the experiment, yet, quickly uplifted by my students, echoing possible ways to revise the procedures and try again. Each attempt and each endeavor, varied as they might be, led me to discover more about myself. I have grown; my teaching of science has become more important to me, and I envision my students' goals more clearly. I have been privileged to be part of a community of learners, recognizing my place among them. I trust I am having input into that level of learning and teaching—contextual learning."[6]

I am making an effort to utilize alternative assessments so that the way I assess students becomes a better teaching process. I want to use alternative assessment along with learning the World Wide Web so that the two are not detached but integrated into the whole process. Fourth-generation evaluation is a reasonable answer to this. This is a form of evaluation in which the claims, concerns, and issues of stakeholders serve as an organizational focus, and it is implemented within the methodological precepts of the constructivist inquiry paradigm.[8]

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## Changes implemented in my classroom

The research I was conducting with the Garden was keyed right into my classroom's thriving, organic, self-sustaining Life Lab garden. In Life Lab each class prepares, maintains, plants, and harvests its own plot, resplendent with flowers, herbs, and vegetables! For seven years, I have developed the garden as a self-sustaining, established focal point for instructional activities in which teachers, students, and parent volunteers join together in stimulating learning activities. Students constantly are required to interact with their immediate environment to discover how the

*Marcie and her students in the organic Life Lab garden.*

*Marcie in the Life Lab garden.*

*GLOBE team taking soil temperature protocols using two thermometers, one 5 cm down, the other 10 cm down. These data are sent along with weather data to the University of Colorado for scientific study.*

*Activities involve estimating, then weighing, measuring circumference, density, length of stem, and number of seeds.*

working systems are independent yet interrelated. I now require the students to have a journal in hand when visiting the garden. My student processes of discovery and inquiry have become more accurate, and they actually enjoy writing, measuring, or sketching their feelings and/or observations. I shall continue to weave assessments and learning into meaningful experiences. We continue to go to the Life Lab garden daily, not just to use our process skills (i.e., observe, measure plant growth, notice soil conditions, classify leaf distribution, characteristics, and similar growth of plants), but to reinforce the concept of all of nature's systems. We even take time to acknowledge what is causing some plants to flourish or die. My eyes have been opened, and so have the eyes of my students.

With all due respect to constructivism, educators cannot negate the important base of all knowledge, which is what students bring to the classroom. As in Bloom's *Taxonomy of Educational Objectives,*[1] beginning with the knowledge and comprehension levels, I have begun to provide my students with more group opportunities to develop better understandings about science and collaboration.[16] However, there were several who took advantage of the enthusiasm and involvement of others. I tried to resolve this by assigning responsibilities (i.e., tasks) for each member of the group. This seemed to help but still required my assistance to keep the group decisions fair and equitable. Consensual agreement requires practice at all ages. Additionally, it became obvious to me that the teaching techniques, whether traditional or constructivist, require monitoring. As a teacher/researcher, I am more involved with learning and able to provide a bridge to enable reflection on action to lead to reflection in action.[13]

Since the constructivist classroom has the potential to provide an environment in which higher-level cognitive learning is enhanced in science, my role has changed to that of facilitator of learning for my students. Students take the responsibility for what is learned. The action research I conducted includes the need to communicate with others about the research. This requirement comes from fundamental beliefs that both teaching and research are activities that occur in communities, and that valued knowledge in those communities must be shared and made public.[3] Having conducted science research in my classroom, I feel fortunate to be able to share my findings with such a distinguished community of teachers. As a teacher/researcher, I hope I will continue to become a reflective practitioner who creates knowledge about teaching and learning as a product of the practice



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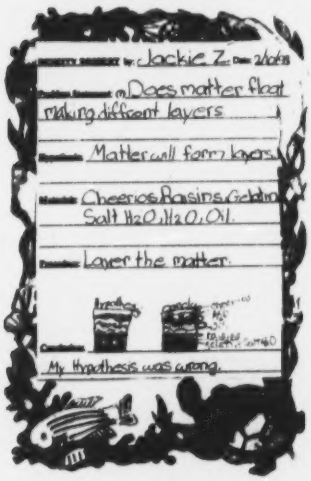
*Compost results: Stinky!*



*Setting up brick crystals for National Chemistry week.*

of teaching.[15] The teacher can help the students develop the roots of knowledge and also empower them with wings. For the teacher, too, there exists a cross-over, a moment of truth when there is no turning back.

*A version of this paper was presented at the annual meeting of the National Association for Research in Science Teaching, April 20, 1998.*

**Marcie L. Bosseler**

Years Teaching: 28

Present Positions:

- K-3 teacher in the Odyssey Center, a primary gifted enrichment program at Palmetto Elementary School, Miami, FL
- Finalist, State Presidential Awards for Excellence in Science
- Teacher/consultant/leader for Urban Systemic Initiative of Miami, Dade County Public Schools
- President, Dade County Science Teachers' Association
- Adjunct professor, Barry University, Adrian Dominican School of Education
- Graduate doctoral student in science education at Florida State University

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*"My own ideas were good ones, but once you have 'felt the researcher's touch' you can never go back to 'quick take' information."*

*"I am a teacher. I was not originally trained as a scientist, but now I am beginning to think like a scientist and feel I am becoming one."*

*"Communication with other scientists allowed me the privilege to peek into their world of problem solving and scientific reasoning."*

*"I felt like the fern, resurrected and growing more toward being a scientist, ready to explore with my students who have so much ahead of them to discover, too!"*

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## Prologue

*Terrie L. Kielborn conducted a qualitative study of the program for seven practicing middle and elementary school teachers. In her chapter,* "Forming Partnerships: How a Teacher Can Become Involved in Scientific Research," *she describes how teachers immersed themselves in scientific research for a semester and often longer. What is needed to make this sort of a program work? How can teachers find similar experiences? How does it impact the students in these teachers' classrooms? Each of these teachers had many reasons for choosing the location, topic, and scientist who would serve as the mentor for the duration of the project. Just think of it! Every one of these teachers had the opportunity to step outside their own culture and enter into another. Seven individuals experienced a new culture for themselves, the culture of science.*

# Forming Partnerships: How a Teacher Can Become Involved in Scientific Research

*Terrie L. Kielborn*

"Culture embraces what people do..."

A culture is formed by a group of people who speak the same language and who pass down a set of customs or mannerisms for a way of life. "Culture embraces what people do, what people know, and things that people make and use."Spradley, 1980, p. 5 as cited in 1 Each of the teachers embraced what a scientist does, what a scientist knows, and took the project that the scientist suggested for scientific investigation. In order for this transformation to take place, each of the teachers learned a new language, developed a new perception of science, and gained knowledge about a particular science concept.

(Excerpt from Lori's paper):

*Working concurrently with a research scientist offers the teacher a first-hand glimpse of the culture and language of science and a chance to immerse oneself in an actual scientific investigation.*

(Excerpt from one of Marcie's e-mails):

*Once you have "felt the researcher's touch," you can never go back to "quick take" information.*

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## What did the teachers say?

As part of this study of how scientific research affected the teachers and their students, we conducted an interpretive study in the hermeneutic tradition.[8] Penny Gilmer or I interviewed each of the teachers for their impressions and feelings about the science research experience. We took pictures of the teachers in their research laboratories.



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I also asked the teachers who wrote chapters for this monograph to answer the following two questions:

1. What advice could you give to a teacher who would like to participate in a science research experience?
2. What are your thoughts on a collaboration of a scientist, a lead practicing teacher (one with leadership, enthusiasm, and known for good teaching), and an undergraduate student who is pursuing science education (also perceived as motivated and willing to learn through new experiences?)

*Summary of thoughts for Question #1:*

It is important to select a topic in which you are interested and about which you would enjoy learning more. Science research requires a great deal of time and energy, and your interest in the subject will give you stamina to complete your project. Planning a time frame that will allow a feasible project to take place is imperative for both scientist mentor and teacher. Both need to be aware of expectations from the onset. Choosing a topic of interest is also important because you will spend a great deal of time reading, and reading, and doing more reading on the subject. Reading about the subject will give you necessary background information for conducting field research and for communicating with the mentoring scientist, others at the laboratory, or the scientific community at large.

*Quotes from teachers for Question #2:*

For question #2, rather than summarize what seven teachers said, I felt that giving excerpts from their e-mails, journals, or conversations was a better way to give you, the reader, a feel for the collective response.

(Excerpt from one of Yvette's e-mails):

*The scientist provides the knowledge of the subject, the teacher provides the creativity and experience of working with children, and the student can do the grunt work and learn at the same time.*

(Excerpt from one of Marcie's e-mails):

*The scientist, lead teacher, and student make a perfect marriage. I think the phrases, "pursuing science...motivated and willing to learn...leadership...enthusiasm and known for good teaching" are excellent assets applicable to all three contributors.*

(Excerpt from one of Joe's e-mails):

*If you are going to teach science, then you must experience and assimilate science as part of the teaching and learning the culture. The learning of science should be realistic and useful. A link can be established to keep both the teacher and student up-to-date on cutting edge research along with changing paradigms in the scientific community.*

(Excerpts from Jackie's interview):

*A lead teacher will bring the expertise and previous classroom experience that a new teacher would not have. For the new teacher (student), this collaboration would allow the opportunity for "real science" thinking and help in developing a philosophy of science*

*and of teaching. The student would come away with a different view of what science is all about and learn teaching strategies from the lead teachers.*

(Excerpt from Terrie's typed answers):

*It is an experience in which each of these members will grow personally and professionally. Each will learn and contribute to the growth of others.*

(Excerpt from Lori's paper):

*The collaboration between a nearby research facility and a teacher's school can provide many rich learning and sharing opportunities for both parties. Immersing one's self, mentally and physically, is far more conducive to true learning.*

*(Excerpt from Kathy's interview):*

*As a teacher, it's just made me much more sensitive to science, discovery, and what they really mean. It's made me a better teacher because I have a lot more patience, and I understand the big picture more than I ever have.*

(Excerpt from one of Joe's e-mails):

*Science goes on around the clock, and when you become involved in field work, time and environmental factors may not be negotiable. Scientists are, by nature, highly motivated and dedicated people.*

---

## Building partnerships

Partnerships are built on collaboration between two or more parties with a mutual interest. Teachers, scientists, students, and university personnel can bring their respective expertise, experience, knowledge, creativity, motivation, energy, and interest together, creating meaningful learning experiences for all. As teachers in this monograph have stated, real science elicits more questions than answers. Students are willing to do "grunt work" that scientists may not have the time or funds to indulge in these investigations. Partnerships offer students the opportunity to be involved and immerse themselves in cutting edge issues while using sophisticated tools and equipment. "Traditional school science has been far from the action, reality, and frontiers of science."[3]

In order to maintain successful partnerships or collaborations such as these teachers experienced, there must be mutual benefit for all concerned. Student and Scientist Partnerships (SSPs) will most likely succeed if they have these three common characteristics:

- They depend on a serious collaboration between science and education.
- They engage students in research of real value to scientists.
- They benefit both science and education.[3, p. 24]

All seven of the teachers who experienced their own scientific research investigation took what they learned and experienced back into their

classrooms. Using criteria suggested by Doubler,[3] it is easy to understand why these partnerships were successful. Each teacher was involved in a serious research investigation relating to his/her interest. The teachers' contributions to research were of real value to the scientists. These teachers did "grunt" work, which was beneficial to participating mentoring scientists. Finally, each teacher somehow integrated real science investigations into their existing curriculum at their schools.

## So, you want to do research?

So, you are convinced that you want to do research—now what? After reading through these seven teachers' experiences with science research, I compiled a list of suggested tips on how to get started:

This is the time to develop partnerships between teachers in schools and scientists in institutions. Scientists may work in state or federal government laboratories, or at science centers and museums, or at community colleges and universities. Begin by making a list of resource persons you know and others who may know of resource persons. Sometimes a great research idea is right under your nose. Talk with colleagues, friends, relatives, or people at your church to get a list of possible scientists to contact. Make some telephone calls and make some visits to get ideas or leads. Sometimes calling one scientist may lead to others to contact. If one doesn't work out, at least he or she can hopefully give you some suggestions of others to call. Last summer, I spent two months trying to line up a scientist, and then just when I was at my wit's end, four came at once. Patience is a big virtue in this respect, but persistence and determination will not hurt your hunt for the "right" research project.

Once you find an interesting topic and a mentoring scientist, you have crossed half of the bridge. Set up a more formal meeting with the scientist involved, discussing some of the details such as days and times to work, special requirements (i.e., lifting, working with hazardous materials or equipment, time-line, possible objects which your experience may entail, appearance, keys, how to obtain materials, etc.), and location. It is better to know what the project entails up front. Also, let them know in the beginning if you have anything planned during the time you will conduct research. Honesty is the best policy to build camaraderie and trust.

An adequate and feasible location will prove very important. Science research takes much time and energy, and it often requires long days or even all-nighters. You want to chose a research site that allows you to fulfill your commitment but at the same time not be a burden to you, your family, or your pocketbook. Lori, Jacqua, and Terrie chose locations close to their homes so that they could maintain their family obligations and even include their family members on occasion to help with their research. Joe, Marcie, Yvette, and Kathy chose locations close to their schools so that their students could work with their mentoring scientists after the research project ended.

## Funding, or how much will this cost me?

One thing you don't want to do is get yourself into a trap where you will have to spend your own money (unless that is your decision to do so). You could find yourself with an interesting research topic that may sound

inviting until you realize it requires traveling a few hundred miles several times within the timeframe of the project. If you have relatives or friends with whom you may stay at another location, that may suit you fine. Otherwise, discuss the possibility of travel reimbursement with your mentoring scientist.

There are programs that offer funding. Teachers Research Update Experience (TRUE) Program offers middle and high school teachers of science, mathematics, and technology funding by way of a stipend, lodging at the University of Florida, and a small grant at the end of the program so teachers can implement what was learned from research experiences with their students. Each teacher in the TRUE Program is paired with a research scientist in a field of interest to the teacher for a seven-week period. Other programs such as Teacher Quest (in the state of Florida) will pay a portion of the teacher's salary over non-contracted months with a business or university paying the remaining salary. For this to occur, the teacher must complete and submit an application, along with an employer from a business or university. This program is also for summer months and is designed to provide the teacher with an opportunity to experience working and learning from a designated mentor.

If you decide to take on a research project, why not earn points for recertification or graduate credit at the same time? This extends the partnership further, including research universities. Many universities offer independent science study courses so that graduate credit can be earned for your efforts. Before taking a course, meet with the supervising professor to discuss the process for taking an independent study course and ask how you will be evaluated. This way you will know what is expected of you, and you can be working toward that goal during the entire research experience.

For our research experiences, we each developed a portfolio of our learning, which we shared with our university research supervisor. In addition, we stayed in e-mail contact with the supervising professor. Our supervising professor, Penny J. Gilmer, visited a number of us at our research sites, to get a better idea of the learning and to communicate with the teacher and research scientist.

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## Teachers learn about the culture of science

The National Science Teachers Association (NSTA) and the National Council of Teachers of Mathematics (NCTM) both endorse the idea of "teacher as researcher" to proclaim professionalism and professional development in teaching.[9] "Mentoring programs, which provide women students with longer term, one-on-one contact with role models, should be strongly supported."[12, p. 22] Teachers in this monograph went beyond constraints of their classrooms, venturing out into the scientific community and actually taking on the role of being a scientist. To accomplish this, a transformation of culture occurred.

These teachers learned that a new language needed to be learned and used as part of their induction to this new culture of science. This language of science was vital for communicating with the mentor and other scientists about the project they were working on.

(Excerpt from Kathy's interview):

*I learned a lot of Latin because Dr. Gleeson taught me how to pronounce all of the crab's names in Latin. And if I mispronounced them, he'd correct me.*

(Excerpt from one of Joe's e-mails):

*It is important to be able to communicate in the language of the scientists and to be fluent enough to transmit understanding.*

As science teachers, we bring into the classroom our perspective of what science is, and that is the view we present to our students. Because of the nature of our educational background, we probably have not had a prior experience of being a scientist or working with a scientist. Seven teachers in this monograph now have had this experience. These teachers dared for a semester to transform themselves from the world of teaching into the world of science. This transformation required a commitment and collaboration between a teacher, a major university professor, and a scientist.

I have had opportunities to hear all but one of the teachers present their papers at a national or state conference. The level of science knowledge learned by this transformation into the scientific culture was truly amazing. Lori comments that she learned more chemistry in her summer science research experience with Dr. Schoor than in all of her chemistry courses combined. Kathy relates that she felt comfortable to ask questions and learned through her mistakes. Teachers are heavily influenced by their experiences in learning science.[6]

Along with language and scientific knowledge came a new perspective. Jacqua and I learned that teamwork is sometimes essential for being able to conduct some types of research.

(Excerpt from Jacqua's journal):

*This study has made me realize the importance of teamwork in science . . . . It was powerful in the connections to real science and real data collection.*

In my own experience with the TRUE program and working with Dr. Phlips, I learned that scientists are very dedicated people who truly immerse themselves in studying and learning about a particular scientific phenomena. But at the same time, I realized that he was a real person who drank tea in the afternoon, who loved to talk about his work, and who had a great sense of humor. Recently, I visited the Environmental Protection Agency (EPA) laboratory where Lori conducted her science research. The first thing Lori and her research mentor did when they saw each other was hug and ask what the other had been up to since they had last met.

Each of the seven teachers found that being a scientist does not separate a person from being human and having feelings and emotions. But these teachers did find scientists are very dedicated and committed people, much like themselves, who were willing to share their knowledge and expertise with them.

Joe used his new scientific knowledge of fish and combined his creativity with prior knowledge of currents to alter the existing anchor that scientists devised into one that actually worked. In his cultural transformation, he learned that scientists do not always have "the" answer. In actuality, a true scientist has more questions than answers.

> *If teachers have the opportunity to be a part of this community of scientists, to engage in the practice of science, then they can understand science from a different perspective than if they had just taken traditional, textbook-oriented science classes.*[7]

These teachers learned to read like a scientist, study like a scientist, record data like a scientist, think like a scientist, and conduct investigations in the field like a scientist. Indeed, for a short time in the life of these seven individuals, they allowed themselves to be transformed from the role of a teacher to the role of a learner and scientist. These transformations had similarities and differences for each of them, but each teacher did experience a life-changing action, which will forever make them different than before.

(Excerpt from Kathy's paper):

*The experience has changed me forever . . . .*

(Excerpt from Lori's paper):

*Never in my life have I wanted to learn about chemicals. Now I want to learn how they affect me, my child, and our world.*

(Excerpt from my own written responses to questions):

*It was fun to feel the wind, get wet, work hard, ache, and know that what I was doing was important. There were people who were depending upon the sample I was collecting to study or conduct tests.*

(Excerpt from Joe's interview):

*It was the best summer of my life. I'd do it again in a heartbeat.*

(Excerpt from Jacqua's interview):

*It was definitely a rewarding learning experience. I learned that many skills from other subject areas must be used when conducting scientific investigations. I didn't realize that a scientist needed map skills to study science.*

---

## These endings bring new beginnings

In this final chapter, I have attempted to unveil the influence each of these teachers had after experiencing the transformation from teacher to scientist. I have used many excerpts from their interviews, papers, or e-mails because I felt that the reader can better understand the thoughts of teachers in the context in which they were written. Phenomena can be understood only within the context in which they are studied.[8] Using excerpts provides the reader with "character traits and provides clues to the speaker's social status, identity, personal style, and interests."[5]

In my interviews and dialogues with the other six teachers, a most common thread appeared throughout—similarities of the cultures of science and education. Joe mentioned in an interview about having to be creative and inventive as a scientist, but his ingenious anchor came from Joe, the teacher. On my visit with Lori at the EPA Lab, she discussed the bureaucracy of working there and then related this to many mandated forms and processes she had to complete as a classroom teacher.

Science and education have much to offer each other. For too long the relationship has been in one direction—science gaining knowledge and education passing it on.[1] If we can encourage this paradigm shift into both cultures gaining and sharing knowledge, partnerships can evolve beyond student, teacher, and scientist to universities, industry, museums, and groups such as SERVE, NSF, SWEPT, TERC, and The Concord Consortium. Imagine scientists having access to an almost unlimited resource of personnel (i.e., our students). They could literally carry out investigations that would normally take years to answer. Pilot studies have shown that children often come up with their own questions when presented with scientific images or data.[10] Fresh, curious eyes would complement the eyes of experience. "They would learn science as it exists in the world and would know how to contribute to its latest questions. The promise is much too great to ignore."[1, p. 26]

One of the great things about science is that there are so many mysteries and so many unanswered questions. Einstein[4] wrote:

> *The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science. Whoever does not know it can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed.*

Seven teachers each had a particular view of science and of scientists. By immersing themselves in the culture of science, they experienced what it was like to live and breathe as a true scientist. They learned the ways of the culture of science. I have only touched the surface of the changes that took place in the lives of these seven people. "Not until we somehow get into the 'black box' of the learner's mind will we know whether many of the things assumed to be detrimental or helpful are indeed influences on a learner."[11, p. 102] The black box between education and science has been opened. Let partnerships crystallize and spread as if seeded by a crystal.

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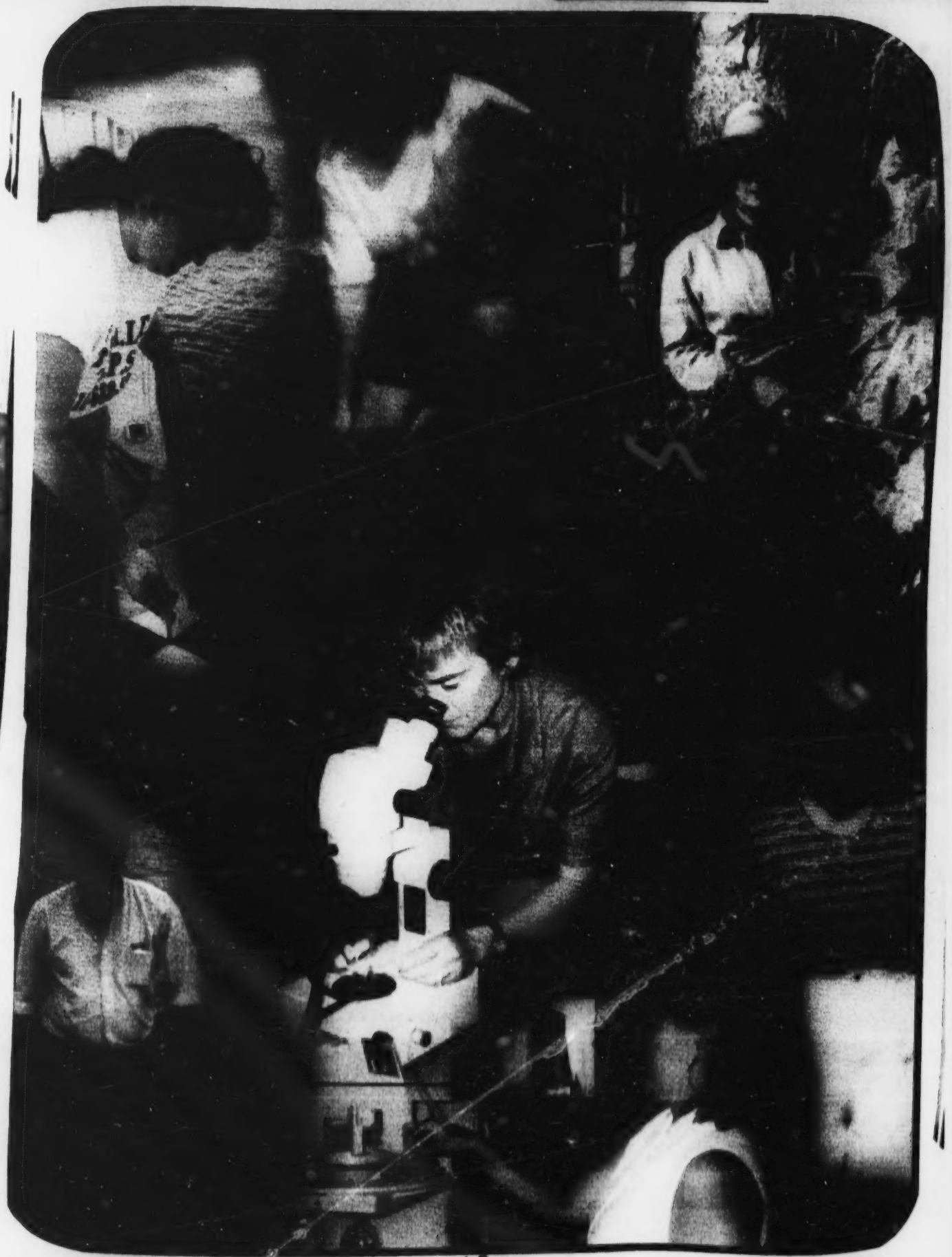

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